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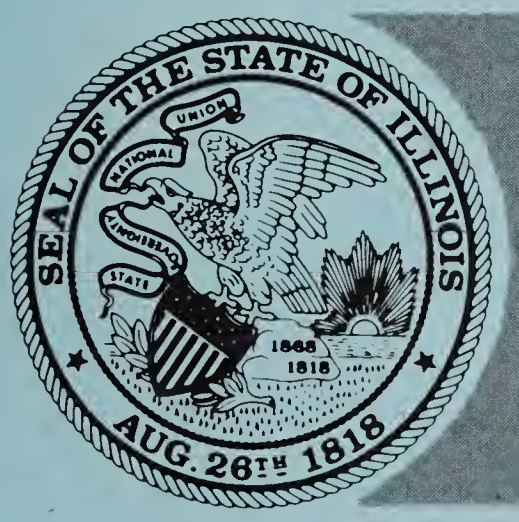

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WOODY INVASION OF GLACIAL DRIFT HILL PRAIRIES IN EAST-CENTRAL ILLINOIS

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ABSTRACT

All encroaching woody species were counted and identified on the Waterworks Ravine Hill Prairie, and on an adjacent degraded remnant that was dominated by prairie vegetation 70 years ago. Woody invading species totaled 9,537 stems/ha on the prairie, while on the degraded remnant there were 47,900 stems/ha. *Euonymus alatus* dominates both sites, while *Viburnum prunifolium* and *Cornus florida* are also common.

INTRODUCTION

Glacial drift hill prairies are grassland openings in forested areas that are usually less than a hectare in size (Hansen, 1922), are on steep, usually south-or southwest-facing slopes and are on unstable glacial till (Costello, 1931). Both glacial drift and loess hill prairies in western Illinois were studied by Evers (1955), while in east-central Illinois Vestal (1918) mapped a series of nine small glacial drift hill prairies just east of Charleston. More recently, Reeves, *et al.* (1978) studied the soil and climate of east-central Illinois glacial drift hill prairies, while Ebinger (1981) surveyed the vegetation of these prairies.

Present observations indicate that glacial drift hill prairies are relatively transient plant communities in east-central Illinois. While small degraded remnants occasionally are found, the few that remain are being rapidly eliminated by encroaching woody vegetation. The present study was undertaken to determine this encroachment on the Waterworks Ravine Hill Prairie, one of the largest still in existence, and compare the results with an adjacent degraded hill prairie remnant that in 1918 Vestal had described as the largest hill prairie in the area.

METHODS

The study area was the region where Vestal (1918) had mapped the extent of nine small glacial drift hill prairies 70 years ago. This area, locally referred to as the Waterworks Ravine, is located about 1 mile east of Charleston, in Coles County, Illinois (Sect. 24, T12N, R9E). The Waterworks Ravine Hill Prairie occurs in this ravine on a steep south- to southwest-facing slope above an intermittent stream that enters Lake Charleston one half mile to the east.

In early Spring of 1988, the size of the remaining prairies in the Waterworks Ravine was determined. Areas with prairie grasses were considered prairie or prairie remnants. Two areas in the ravine were chosen for future study, one being the Waterworks Ravine Hill Prairie (Area A), and one a degraded prairie remnant (Area B) described by Vestal (1918) as the largest hill prairie in the area.

The entire Waterworks Ravine Hill Prairie (Area A) was divided into 2 × 2 m plots (136 plots). In the degraded remnant (Area B) a quadrat 10 m on a side was placed in the area where some prairie species were still found, and divided into 2 × 2 m plots (25 plots). All woody plants that usually are not associated with prairies were counted, identified (Mohlenbrock, 1975), and their frequencies and densities (stems/ha) calculated for both areas.

RESULTS AND DISCUSSION

Of the nine glacial drift hill prairies mapped by Vestal (1918) one remains a hill prairie with typical prairie vegetation, three other small remnants degraded by woody species encroachment could be located, while no trace exists of the other five. Of these nine areas, the one described by Vestal (1918) as "mostly bare clay with scattered bunches of *Andropogon scoparius*", is now the best quality hill prairie being 544m^2 in size (Area A). The prairie area described as the largest is now a small remnant degraded by woody species encroachment, and was used as a comparison plot (Area B). It is about 30 m west of Area A.

Area A is presently dominated by a fairly dense stand of *Sorghastrum nutans* (L.) Nash., while *Euphorbia corollata* L., *Melilotus alba* Desr., *Silphium terebinthinaceum* Jacq., *Solidago nemoralis* Ait. and *Physostegia virginiana* (L.) Benth. are the common forbs. Prairie shrubs include *Ceanothus americanus* L. and *Rosa carolina* L. (Ebinger, 1981; Reeves *et al.*, 1978). Within the plots of Area A, 23 invading woody species were found, averaging 9,537 stems/ha (Table 1). *Euonymus alatus* is the dominant invading species of this area with 2,518 stems/ha, and a frequency of 32%. *Cornus florida*, *Viburnum prunifolium*, *Ostrya virginiana*, and *Quercus velutina* also are common, averaging between 1,710 and 735 stems/ha, and having frequencies of 15% or higher.

In the degraded glacial drift hill prairie, Area B, 17 encroaching woody species were found in the plots, averaging 47,900 stems/ha (Table 1). Again, *Euonymus alatus* is the most commonly encountered species, averaging 13,100 stems/ha, and being found in all of the plots examined. Other common species include *Viburnum prunifolium*, *Toxicodendron radicans*, *Cornus florida*, and *Diospyros virginiana*, averaging between 7,900 and 4,900 stems/ha, and having frequencies of 68% or higher. In both areas most of the woody individuals are less t han 2.5 cm dbh, while none were encountered with a dbh greater than 12.5 cm.

Of the invading woody species, *Euonymus alatus* dominates on both areas. Other common invaders in both areas are *Viburnum prunifolium* and *Cornus florida*, while *Quercus velutina* is common in Area A, but is relatively unimportant in Area B. Also, Area A has a higher diversity of invading species with *Hydrangea arborescens*, *Quercus muhlenbergii*, *Tilia americana* L., *Carya ovata* (Mill.) K. Koch., *Liriodendron tulipifera* L., *Viburnum recognitum* Fern., *Rhamnus cathartica* L., *Crataegus mollis* (T. & G.) Scheele, and *Rhus glabra* L. being found here but not in Area B. In contrast, *Toxicodendron radicans* and *Diospyros virginiana* are common invading species in Area B, but not in Area A; while *Diospyros virginiana*, *Acer saccharum*, and *Xanthoxylum americanum* Mill. are absent from Area A.

Euonymus alatus (burning-bush) was reported as naturalized in Illinois by Ebinger and Phillippe (1973). This species, which is native to eastern Asia, is a commonly planted ornamental that is becoming a problem in some natural areas (Ebinger, 1983). In the woods the Waterworks Ravine, burning-bush has an abundance about 10 times greater than that recorded for all other woody species combined. Ebinger (1983) found that *E. alatus* seedlings exceeded 150,000 stems/ha, saplings averaged 1,700 stems/ha, with some individuals more than 5 cm dbh and exceeding 30 years in age. The present data suggest that this species will be a major invader of glacial drift hill prairies when a seed source occurs in the immediate area.

In general, the total number of woody invading species encountered in plots at the edge of Area A are much higher than the number found in the inner plots, where many plots lack woody invading species. In the plots at the edge of study Area A, woody plants average 17,666 stems/ha, while in the inner plots woody plants average 3,125 stems/ha. This indicates that encroachment is taking place at the edge of the prairie. It appears that shading by surrounding woody vegetation may be creating a microclimate favoring the woody invading species at the expense of the natural prairie vegetation. If this trend continues on the Waterworks Ravine Hill Prairie, woody species encroachment will eliminate this prairie within the next 70 years.

LITERATURE CITED

Costello, D.F. 1931. Comparative study of river bluff succession on the Iowa and Nebraska sides of the Missouri River. Bot. Gaz. 91:295-307.

Ebinger, J.E. 1981. Vegetation of glacial drift hill prairie in east-central Illinois. Castanea 46:115-121.

Ebinger, J.E. 1983. Exotic species: A potential problem in natural area management in Illinois. Nat. Areas Jour. 3:3-5.

Ebinger, J.E. and L.R. Phillippe. 1973. New plant records for Illinois. Trans. Ill. St. Acad. Sci. 66(3 & 4):115.

Evers, R.A. 1955. Hill prairies of Illinois. Ill. Nat. Hist. Sur. Bull. 26:367-446.

Hansen, H.C. 1922. Prairie inclusions in the deciduous forest climax. Amer. Jour. Bot. 9:330-337.

Mohlenbrock, R.H. 1975. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale and Edwardsville.

Reeves, J.T., U.D. Zimmerman, and J.E. Ebinger. 1978. Microclimatic and soil differences between hill prairie and adjacent forests in east-central Illinois. Trans. Ill. St. Acad. Sci. 71(2):156-164.

Vestal, A.G. 1918, Local inclusions of prairie within forest. Trans. Ill. St. Acad. Sci. 11:122-126.

Table 1. Frequency (%) and density (stems/ha), of all woody stems encountered on the Waterworks Ravine Hill Prairie (Area A), and on an adjacent degraded glacial drift hill prairie (Area B).

	AREA A		AREA B	
	Freq. %	Density (stems/ha)	Freq. %	Density (stems/ha)
Euonymus alatus Thunb.	32	2518	100	13100
Cornus florida L.	26	1710	72	5600
Viburnum prunifolium L.	18	1176	68	7900
Ostrya virginiana (Mill.) K. Koch	18	1066	32	1700
Quercus velutina Lam.	15	735	4	200
Hydrangea arborescens L.	2	478	—	—
Malus ioensis (Wood) Britt.	9	422	20	800
Lonicera maackii Maxim.	7	220	44	1600
Fraxinus americana L.	6	202	40	1600
Toxicodendron radicans (L.) Kuntze	4	202	72	6700
Ligustrum vulgare L.	6	165	36	1300
Quercus muhlenbergii Engelm.	4	110	—	—
Liriodendron tulipifera L.	3	110	—	—
Cercis canadensis L.	2	74	36	1300
Diospyron virginiana L.	—	—	68	4900
Acer saccharum Marsh.	—	—	8	500
Elaeagnus umbellata Thunb.	1	74	8	200
Others	—	275	—	500
TOTALS	—	9537	—	47900

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AQUATIC HYPHOMYCETE COMMUNITIES IN CLEAR-CUT AND WOODED AREAS OF AN ILLINOIS STREAM

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ABSTRACT

Aquatic hyphomycete communities in wooded and clear-cut areas of Jordan Creek, Vermilion County, Illinois, were compared using leaf pack baits and membrane filtration of stream water. Number of species per unit substrate, species richness, diversity (H'), number of conidia per liter of stream water, and degree of colonization of substrate were all greater in wooded areas and adjacent down-stream clear-cut sites than in an up-stream clear-cut site. Wooded patches on clear-cut streams could serve to maintain diversity and inoculum levels of aquatic fungal decomposer communities.

INTRODUCTION

Ingold, in a series of papers initiated in 1942 (Ingold, 1942), described a number of fungi with tetraradiate and sigmoid conidia found in foam and on submerged leaves and twigs in streams in England. A few of these fungi, now generally referred to as the freshwater aquatic hyphomycetes, had been described earlier by de Wildeman (1893, 1894, 1895), Kegel (1906) and Karling (1935). In recent years, many additional species have been described and much information on the taxonomy and geographical distribution of these fungi has accrued (Webster and Descals, 1981). A common substratum for aquatic hyphomycetes in streams is deciduous leaves of riparian origin (Nilsson, 1964; Ingold, 1975; Webster and Descals, 1981).

Leaves of riparian origin comprise a large portion of the total fixed carbon

available in streams to heterotrophic organisms at successive trophic levels (Cummins, 1974). Aquatic hyphomycetes play an important role in increasing the palatability and nutritional quality of deciduous leaves for invertebrate grazers (Bärlocher and Kendrick, 1973a and b, 1975), while at the same time enzymatically degrading the leaves (Suberkropp et al., 1983; Chamier and Dixon, 1982). The role of aquatic hyphomycetes is especially important because many aquatic invertebrate grazers which are unable to digest cellulose and lignin are able to use fungal biomass generated by leaf-decomposing fungi.

Although some work has been done on the enzymatic activities of aquatic hyphomycetes (Hewings and Shearer, 1981; Chamier and Dixon, 1982; Suberkropp et al., 1983; Chamier, 1985) and their suitability as a food resource to invertebrates (Bärlocher and Kendrick, 1973a and b), little is known about the factors which regulate the structure of their communities. Environmental factors known thus far to affect aquatic hyphomycete community structure are: seasonality (Nilsson, 1964; Iqbal and Webster, 1973b, 1977; Bärlocher and Rosset, 1981; Shearer and Webster, 1985); pH (Suzuki and Nimura, 1961; Wood-Eggenschwiler and Bärlocher, 1983); temperature (Suberkropp, 1984); and quality of riparian vegetation (Iqbal and Webster, 1977; Bärlocher and Rosset, 1981).

A number of streams and creeks in midwestern agricultural areas have been channelized and have had their riparian vegetation removed (clear-cutting) to facilitate drainage. There has been no effort thus far to investigate the effects of removal of riparian woodland vegetation on aquatic hyphomycete community structure. Jordan Creek, which originates in croplands in Vermilion County, Illinois, is clear-cut at its origin but has subsequent patches of riparian woodland alternating with additional clear-cut areas. This stream afforded the opportunity to investigate the effects of absence of riparian woodland vegetation on leaf-colonizing aquatic hyphomycete communities.

MATERIALS AND METHODS

Description of Study Site

A portion of Jordan Creek near Fairmount, Illinois, with alternately clear-cut and wooded areas was selected for study. The first sampling site was located in the clear-cut portion of the stream above the first wooded area of the stream. The second sampling site was located at the beginning of the first wooded area and sites three through six were within the first wooded area. The seventh and eighth sites were located in the second clear-cut area. During the second filtration experiment, two more stations were added, the ninth within the second clear-cut area and the tenth at the beginning of the second wooded area. The distance between each station was approximately one-quarter mile.

Physical and Chemical Parameters

Physical and chemical parameters measured were: temperature, pH, dissolved oxygen, carbon dioxide, and alkalinity bicarbonates. All parameters were determined with standard techniques (Lind, 1979). Temperature and carbon dioxide were measured in the field. Dissolved oxygen was fixed in the field and samples returned to the laboratory in a cooler for titration. Separate samples were taken in plastic containers and returned to the laboratory in a cooler for determination of pH (Corning pH Meter Model 7) and alkalinity (titration with 0.02 N H_2SO_4).

Aquatic Hyphomycete Community Structure

Submerged plant debris was collected and examined with the compound microscope for aquatic hyphomycete species which were identified. To sample conidia of aquatic hyphomycetes in water, two 500 ml Buchner flasks equipped with 250 ml plastic millipore filtration funnels containing membrane filters of 0.45 um pore size were connected together with a rubber tube (0.5 cm diam.) to a common pressure resistant, rubber tube of the same diameter. A three-way plastic valve was placed at the end of the rubber tube and fitted to a 65 ml syringe, which was used to create a vacuum. Six 250 ml water samples collected with a bucket were filtered directly in the field at each sampling site. Conidia on membrane filters were fixed and stained with cotton blue in lactic acid and quantified according to the procedures of Shearer and Lane (1983).

Leaves of oak (*Quercus macrocarpa* Michx.), collected in November, 1982, from a single tree on the campus of the University of Illinois, were soaked briefly in distilled water, stacked in packs of five, and sewn together by passing nylon fishing line through their centers several times. Packs were tied to bricks (three packs per brick). Three bricks were placed at each station, about 30-50 cm below the water surface on December 7, 1982. Six weeks later, on January 21, 1983, leaf packs were removed from each brick, placed in plastic bags and returned in a cooler to the laboratory, where they were separated and washed in distilled water. Ten leaf disks were cut from each leaf with a paper hole punch, and incubated for 48 hours in Petri dishes with sterilized distilled water at 7 C (stream temperature at time of sample collection). Oak leaves were selected because they are processed fairly slowly (Petersen and Cummins, 1974), and therefore allow the establishment of a fungal community without rapid disintegration of the substratum. Leaf disks were fixed in lactic acid with cotton blue and examined microscopically for loose and developing conidia of aquatic hyphomycetes. Fungi on disks were quantified and colonization estimated subjectively according to the techniques of Shearer and Lane (1983). Quantitative data on occurrences of fungi are reported in two categories: (1) only fungi whose conidia are attached to conidiophores attached to the leaf, and (2) attached conidia as in (1) and loose conidia. The first category reflects those individuals actually growing on the leaf disk and the second category reflects those that are growing on the leaf disk and those that may have been produced on the examined leaf and/or those produced on other leaves and trapped by the examined leaf. Data in the first category will be presented first and without parentheses and data in category 2 will be presented second and within parentheses throughout the paper.

RESULTS

Physical and Chemical Measurements

Physical and chemical measurements are presented in Figure 1. Temperatures ranged from 6 to 8 C, with generally higher temperatures within the wooded area; pH ranged from 6.8 to 7.4, with the lowest pH in the wooded area (Fig. 1A). Alkalinity ranged from 182-240 mg/l and was lower in the wooded area (Fig. 1B). Dissolved oxygen ranged from 11.2 to 12.3 mg/l and was lower in the wooded area (Fig. 1C), while carbon dioxide ranged from 3.7 to 7.0 mg/l with the greatest concentration occurring at the end of the wooded area (Fig. 1D).

Aquatic Hyphomycete Community Analysis

The mean number of conidia per liter increased greatly within the wooded area of the stream and then decreased in the following clear-cut area (Fig. 2A). Differences in conidial numbers between clear-cut and wooded areas were not as great in the March sample (Fig. 2B), but still followed the same general pattern evident in November. In March, samples were taken in a second downstream wooded area (Site 10), and conidial numbers increased as they did in the first wooded area (Fig. 2B).

The mean degree of colonization of leaf disks by aquatic hyphomycetes increased within the wooded area and decreased in the second clear-cut area (Fig. 2C). The mean number of species per disk (Table 1) and per leaf (Table 2) was also greater in wooded than in clear-cut areas. Relative importance values for each species at each site are presented in Table 3 and Shannon and Weaver diversity indices (H') calculated from these data were higher in the wooded than in clear-cut areas (Table 3). More species were detected with leaf pack baits than with membrane filtration and examination of natural substrata (Table 4).

DISCUSSION

The finding that more conidia per liter of aquatic hyphomycete species were found in wooded than clear-cut areas of the same stream suggests that quantity of substrata strongly affects the size of populations of these fungi. In support of this hypothesis is the decrease in number of conidia per liter in the wooded area in March, when amount of deciduous leaf litter is naturally low. Similar seasonal declines in number of conidia per liter have been observed by Iqbal (1973) and Shearer and Webster (1985b).

The greater number of species per leaf and per unit area of leaf (disk) and the higher degree of colonization of leaf disks from oak leaf packs in the wooded area compared to the clear-cut areas probably resulted from the higher inoculum levels present in the wooded area. The greater the number of conidia per liter, the greater the probability for colonization to occur. The same trends were observed for naturally non-wooded and wooded areas of a river in England (Shearer and Webster, 1985a). In the English river, lower number of species per leaf and disk and lower degree of colonization were also linked to lower inoculum levels resulting from the small quantity of substrata and low pH. In Jordan Creek, the greatest difference in pH between any wooded and clear-cut site was approximately ½ unit. Since pH fluctuated around pH 7 and differences between sites were small, pH probably was not responsible for differences between clear-cut and wooded areas and quantity of substrata is probably the most important factor.

Lower temperatures (2 C) in the clear-cut area may have reduced sporulation of some aquatic hyphomycetes. Generally, however, most autumn species of temperate aquatic hyphomycetes grow and sporulate at low temperatures (Webster and Descals, 1981). As a result of greater photosynthesis in clear-cut areas due to the release of light limitation from riparian trees, oxygen levels are higher in clear-cut areas during the day. In addition, during the fall, leaf litter added to the stream in the wooded area is colonized by microorganisms which use oxygen and produce CO_2. Thus during the day, at the time of leaf fall, clear-cut areas of Jordan Creek are higher in oxygen and lower in CO_2 than wooded areas. It is commonly

thought that aquatic hyphomycetes are more common in well-aerated streams (Ingold, 1975), but in Jordan Creek, populations of aquatic hyphomycetes are greater in wooded areas with relatively less dissolved oxygen and more CO_2 than in clear-cut areas. It is possible that dissolved oxygen and CO_2 did not reach levels limiting growth and sporulation of aquatic hyphomycetes and the presence of abundant substrata masked any negative effects of low O_2/CO_2 ratios in the wooded area. Further experimental work is needed to determine the effect(s) of dissolved gases on growth and sporulation of aquatic hyphomycetes.

Distinct differences in species composition between wooded and clear-cut areas did not occur, rather the community in the wooded area was richer than in the clear-cut area by four species (*Tricladium angulatum*, *Alatospora constricta*, *Lemonniera pseudofloscula* and *L. aquatica*) (Table 4). This contrasts sharply with the distinct species compositional differences between wooded and unwooded areas which occurred in the River Teign in England (Shearer and Webster, 1985a). Differences in the River Teign were attributed to differences in pH and substrata. Since pH can probably be ruled out as a factor in Jordan Creek, quality and/or quantity of substrata may be responsible for differences in species composition and numbers. H' diversity also was greater in the wooded than clear-cut areas, not only because of the addition of new species but also because of the greater equity with which frequencies of occurrence were distributed among species (Table 3).

The overall low number of species of aquatic hyphomycetes found in Jordan Creek contrasts sharply with higher numbers of species found in other streams studied (Barlocher and Rosset, 1981; Iqbal and Webster, 1973b, 1977; Shearer and Webster, 1985a). This suggests that the overall effect of stream channelization and clear-cutting may be harmful to aquatic hyphomycete communities. Since no permanent headwater streams that are not unchannelized and clear-cut exist in this region of East-Central Illinois, we have no idea what species may have comprised aquatic hyphomycete communities prior to land modification for agriculture and drainage. The range and mean number of species per disk and per leaf is lower than that found on sixty randomly sampled leaves in the Sangamon River, Illinois, a river also located in East Central Illinois. All of the species found in Jordan Creek also occur in the Sangamon River (Shearer, Unpubl. data).

Clearly, species diversity, H' diversity, numbers of species per unit resource and species activity (as measured by degree of colonization) were all higher in wooded than in clear-cut areas of Jordan Creek. Establishment of wooded patches on clear-cut streams should be considered as a management option that would improve the biological integrity of agrarian streams. Not only would decomposer fungal diversity and inoculum levels be increased, but leaves and woody debris would serve as a carbon source and habitat for stream heterotrophs other than fungi.

LITERATURE CITED

Bärlocher, F. and B. Kendrick. 1973a. Fungi in the diet of *Gammarus pseudolimnaeus* (Amphipoda). Oikos 24:295-300.

Bärlocher, F. and B. Kendrick. 1973b. Fungi and food preferences of *Gammarus pseudolimnaeus*. Arch. Hydrobiol. 72:501-506.

Bärlocher, F. and B. Kendrick. 1974. Dynamics of the fungal population on leaves in a stream. J. Ecol. 62:761-791.

Bärlocher, F. and B. Kendrick. 1975. Assimilation efficiency of *Gammarus pseudolimnaeus* (Amphipoda) feeding on fungal mycelium or autumn-shed leaves. Oikos 26:55-59.
Bärlocher, F. and J. Rosset. 1981. Aquatic hyphomycete spora of two black forest and two Swiss Jura streams. Trans. Br. Mycol. Soc. 71:1-5.
Chamier, A. 1985. Cell-wall-degrading enzymes of aquatic hyphomycetes: a review. Bot. J. Linn. Soc. 91:67-81.
Chamier, A.C. and P.A. Dixon. 1982. Pectinases in leaf degradation by aquatic hyphomycetes: the enzymes and leaf maceration. J. Gen. Microbiol. 128:2469-2483.
Cummins, K.W. 1974. Structure and function of stream ecosystems. Bioscience 24:631-641.
de Wildeman, E. 1893. Notes mycologiques. Fascile 2. Ann. Soc. Belge. Micro. 17:36-58.
de Wildeman, E. 1894. Notes mycologiques. Fascile 3. Ann. Soc. Belge. Micro. 18:135-161.
de Wildeman, E. 1895. Notes mycologiques. Fascile 6. Ann. Soc. Belge. Micro. 19:191-232.
Hewings, A.D. and C.A. Shearer. 1981. Growth studies of *Filosporella annelidica* (aquatic hyphomycete). Mycologia 73:542-550.
Ingold, C.T. 1942. Aquatic hyphomycetes of decaying alder leaves. Trans. Br. Mycol. Soc. 25:339-417.
Ingold, C.T. 1975. The morphology and biology of freshwater fungi excluding phycomycetes. Pp 335-357. *In* Recent Advances in Aquatic Mycology. Ed. E.B.G. Jones, Halsted Press, John Wiley and Sons, NY.
Iqbal, S.H. 1976. Effect of pH on sporulation of freshwater hyphomycetes. Biologia. 22:144-153.
Iqbal, S.H. and J. Webster. 1973. Aquatic hyphomycete spora of the River Exe and its tributaries. Trans. Br. Mycol. Soc. 61:331-346.
Iqbal, S.H. and J. Webster. 1977. Aquatic hyphomycete spora of some Dartmoor Streams. Trans. Br. Mycol. Soc. 59:233-241.
Karling, J.S. 1935. *Tetracladium marchalianum* and its relation to *Astrothrix*, *Phycastrum*, and *Cerastrias*. Mycologia 27:478-495.
Kegel, W. 1906. *Varicosporium elodeae*, ein wassepilz mit auffallender konidienbildung. Ber. Dtsch. Bot. Ges. 24:213-216.
Lind, O.T. 1979. Handbook of Common Methods in Limnology. Mosby Publ., St. Louis. 199 pp.
Nilsson, S. 1964. Freshwater hyphomycetes. Taxonomy, morphology and ecology. Symb. Bot. Upsal. 18:1-130.
Petersen, R.C. and K.W. Cummins. 1974. Leaf processing in a woodland stream. Freshwater Biol. 4:343-363.
Shearer, C.A. and L.C. Lane. 1983. Comparison of three techniques for the study of aquatic hyphomycete communities. Mycologia 75:498-508.
Shearer, C.A. and J. Webster. 1985a. Aquatic hyphomycete community structure in the River Teign, Devon, England. I. Longitudinal distribution patterns. Trans. Br. Mycol. Soc. 84:489-501.
Shearer, C.A. and J. Webster. 1985b. Aquatic hyphomycete community structure in the River Teign, Devon, England. II. Temporal distribution patterns. Trans. Br. Mycol. Soc. 84:509-518.
Suberkropp, K. 1984. Effect of temperature on seasonal occurrence of aquatic hyphomycetes. Trans. Br. Mycol. Soc. 82:53-62.
Suberkropp, K., T.L. Arsuffi, and J.P. Anderson. 1983. Comparison of degradative ability, enzymatic activity, and palatibility of aquatic hyphomycetes grown on leaf litter. App. and Environ. Microbiol. 46:237-244.
Suzuki, S. and H. Nimura. 1961. Relation between the distribution of aquatic hyphomycetes in Japanese lakes and lake types. Bot. Mag. 74:51-55.
Webster, J. and E. Descals. 1981. Morphology, distribution and ecology of conidial fungi in freshwater habitats. *In* Biology of Conidial Fungi pp. 295-355. Ed. G.C. Cole and B. Kendrick. Academic Press, Inc., NY.
Wood-Eggenschwiler, S. and F. Bärlocher. 1983. Aquatic hyphomycetes in sixteen streams in France, Germany and Switzerland. Trans. Br. Mycol. Soc. 81:371-379.

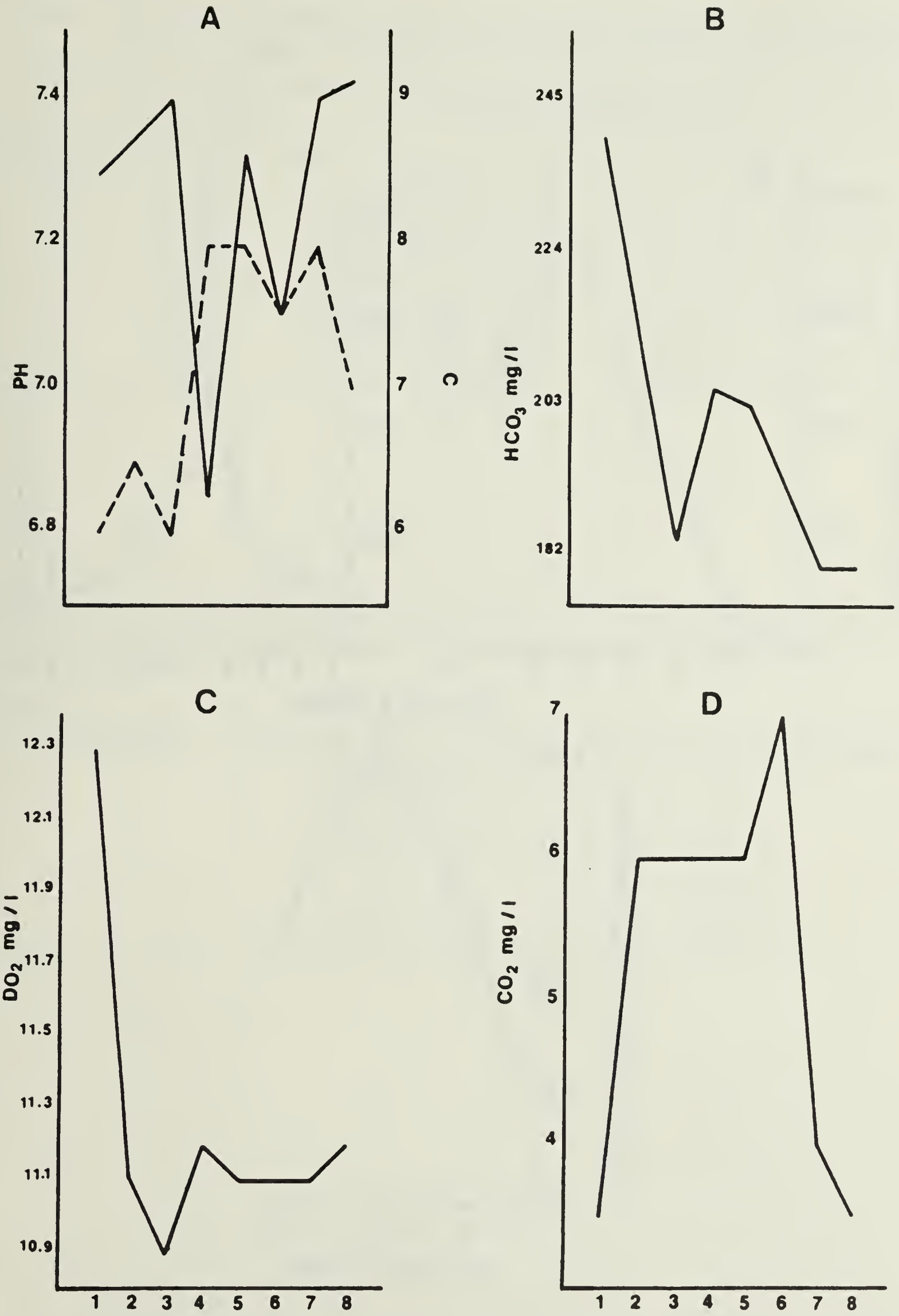

Figure 1. Physical and chemical water-quality measurements at stations 1-8, November 17, 1982: A. temperature (C) (------) and pH (——); B. alkalinity (HCO_3 in mg/l); C. dissolved oxygen (mg/l); and D. carbon dioxide (mg/l).

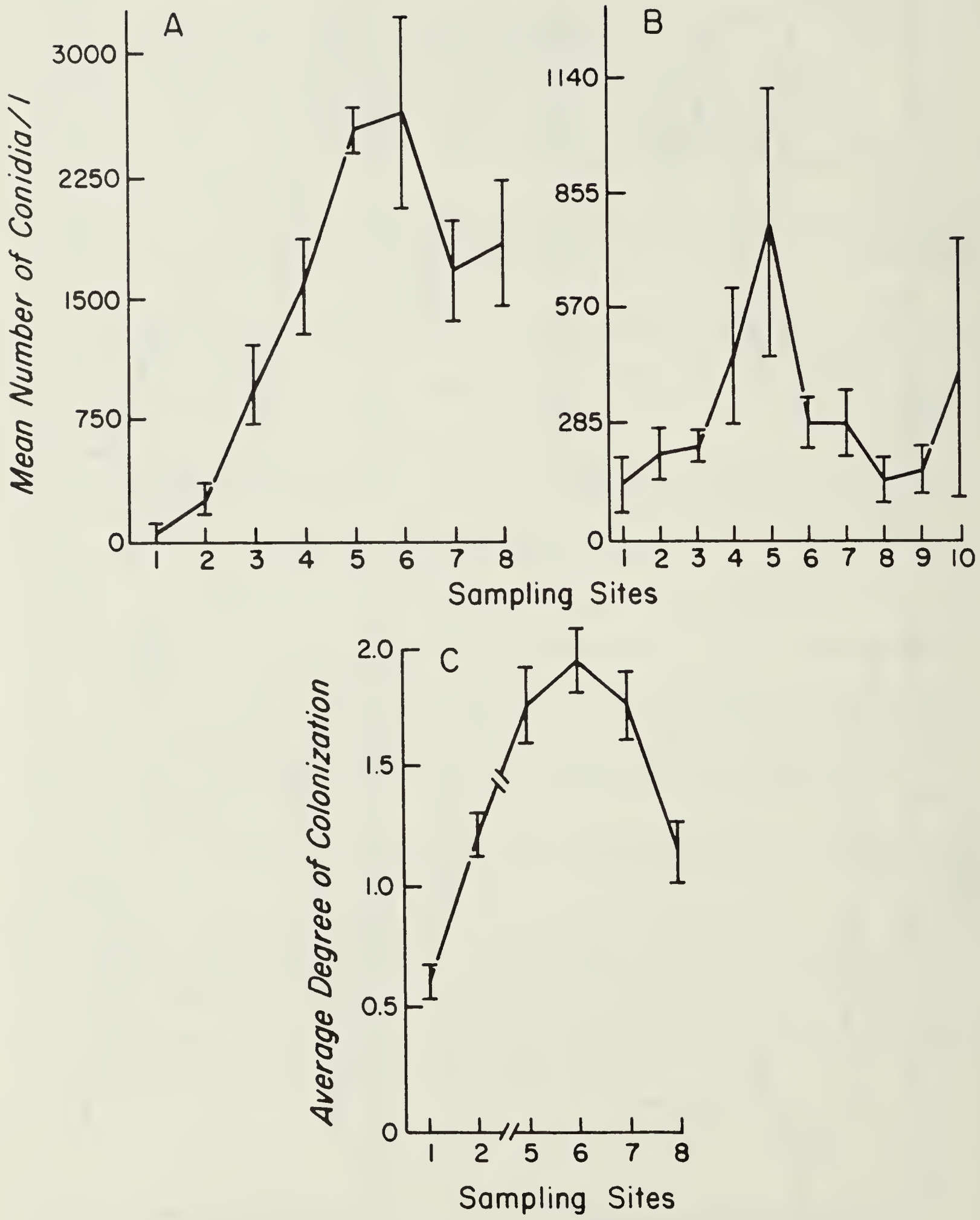

Figure 2. A, B. Mean number of conidia of aquatic hyphomycetes per liter of stream water at each sampling site. (Mean of six 250 ml samples at each sampling site ±95% confidence interval). A. November 17, 1982. B. March 4, 1983. C. Average degree of colonization of leaf disks, subjectively ranked on a scale of 0-5. (Mean of 200 disks/station ±95% confidence interval).

Table 1. The mean number of aquatic hyphomycete species on oak leaf disks from leaf packs submerged from December 7, 1982 to January 21, 1983.

Sampling Site	No. of Disks Colonized n = 200	Mean No. of Species/Disk	
		All Disks	Only Colonized Disks
1	123(191)	1.04 ±0.14 (2.39 ±0.13)	1.69 ±0.10 (2.50 ±0.11)
2	177(199)	0.79 ±0.16 (3.42 ±0.13)	2.03 ±0.14 (3.44 ±0.13)
5	182(193)	1.64 ±0.13 (2.74 ±0.13)	1.80 ±0.12 (2.84 ±0.11)
6	199(200)	2.05 ±0.14 (2.66 ±0.14)	2.06 ±0.14 (2.66 ±0.14)
7	185(190)	1.60 ±0.13 (1.99 ±0.15)	1.71 ±0.12 (2.07 ±0.14)
8	149(189)	1.41 ±0.16 (2.27 ±0.14)	1.89 ±0.13 (2.40 ±0.12)

Table 2. The mean and range in number of aquatic hyphomycete species on oak leaves from packs submerged from December 7, 1982 to January 21, 1983.

Sampling Site	Minimum, Mean and Maximum Number of Species/Leaf	
1	1- 2.75 ±0.34 -4	(1- 3.30 ±0.31 -4)
2	3- 4.25 ±0.43 -6	(4- 5.45 ±0.47 -8)
5	2- 3.45 ±0.42 -5	(2- 4.20 ±0.45 -6)
6	3- 4.25 ±0.45 -7	(3- 4.70 ±0.49 -7)
7	1- 3.45 ±0.56 -5	(2- 4.15 ±0.51 -6)
8	2- 3.10 ±0.40 -5	(3- 3.30 ±0.31 -5)

Table 3. Relative importance values (RIV)* for individual species on leaves in leaf packs and Shannon-Weaver index of diversity (H')** at each sampling site

Species	Sampling Sites											
	1		2		5		6		7		8	
Clavariopsis aquatica	0.801	(0.694)	0.558	(0.466)	0.516	(0.581)	0.380	(0.394)	0.480	(0.511)	0.678	(0.662)
Filosporella annelidica	0.645	(0.635)	0.522	(0.460)	0.753	(0.561)	0.546	(0.481)	0.715	(0.594)	0.680	(0.618)
Tetracladium marchalianum	0.484	(0.524)	0.395	(0.401)	0.420	(0.453)	0.373	(0.429)	0.304	(0.365)	0.454	(0.486)
Alatospora acuminata	0.045	(0.045)	0.100	(0.123)	0.017	(0.027)	0.042	(0.041)	0.044	(0.070)	—	—
A. constricta	—	—	0.109	(0.183)	0.058	(0.150)	0.117	(0.123)	0.086	(0.095)	0.132	(0.174)
Tricladium terrestre	0.022	(0.022)	0.208	(0.195)	0.129	(0.100)	0.154	(0.138)	0.129	(0.126)	0.030	(0.022)
T. angulatum	—	—	0.000	(0.012)	—	—	0.014	(0.016)	—	—	—	—
Tripospermum myrti	—	—	0.043	(0.101)	0.085	(0.112)	0.370	(0.349)	0.239	(0.206)	0.023	(0.034)
Lemonniera pseudofloscula	—	—	0.060	(0.043)	—	—	—	—	—	—	—	—
L. aquatica	—	—	0.000	(0.012)	0.017	(0.013)	0.000	(0.012)	0.000	(0.014)	—	—
Triscelophorus acuminatus	—	—	—	—	—	—	—	—	0.000	(0.014)	—	—
Unidentified species	—	—	—	—	—	—	0.000	(0.012)	—	—	—	—
H' Diversity	1.03	(1.10)	2.15	(2.45)	1.69	(1.95)	2.17	(2.28)	1.90	(2.08)	1.35	(1.42)

*Relative Importance Values = A+B where
A = species relative frequency on leaves = leaf frequency of a species ÷ leaf frequency of all other species and
B = species relative frequency on disks = mean disk frequency ÷ mean disk frequency for all other species

**$H' = P_i \ln p_i$ where, $P_i = A+B$

Table 4. Presence of aquatic hyphomycetes on naturally occurring substrata, oak leaf packs, and in filtered water.

	Natural Substratum		Leaf Packs		Filtered Water	
	clear-cut	wooded	clear-cut	wooded	clear-cut	wooded
Clavariopsis aquatica de Wildeman		+	+	+	+	+
Filosporella annelidica (Shearer & Crane) Crane & Shearer		+	+	+	+	+
Tetracladium marchalianum de Wildeman	+	+	+	+	+	+
Alatospora acuminata Ingold	+	+	+	+	+	+
A. constricta Dyko				+		+
Tricladium terrestre Park			+	+		
T. angulatum Ingold		+		+		+
Tripospermum myrti (Lind) Hughes	+	+	+	+		+
L. pseudofloscula Dyko				+		
L. aquatica de Wildeman		+		+		
Triscelophorus acuminatus Nawawi			+		+	+

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SILPHIUM TRIFOLIATUM IN ILLINOIS

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ABSTRACT

The first record of occurrence of *Silphium trifoliatum* in Illinois is reported.

RESULTS AND DISCUSSION

While at the candidate Barker Bluff Research Natural Area, Hardin County, Illinois, a small population of *Silphium trifoliatum* L. was found by staff members of the Natural Land Institute. This represents the first record of occurrence of this species in Illinois.

Four stems of *Silphium trifoliatum* were observed near the edge of dry upland forest in a somewhat shaded site, but open limestone glade habitat was less than 10m away. Tentative identification of the plants was made in the field based on the authors familiarity with the species in southern Indiana. Identification was confirmed by using keys to *Silphium* in Fernald (1950) and Gleason (1952). The range of this species is given in these volumes as Pennsylvania and Indiana south to South Carolina, Georgia, and Alabama. Habitats given include woods, openings, and prairies.

Barker Bluff has remnants of what was probably the largest limestone glade system in Illinois. Parts of the bluff to either end have been destroyed by quarrying. The research natural area candidate is on land managed by the Shawnee National Forest. Barker Bluff was first recognized as a significant natural area during the Illinois Natural Areas Inventory. Communities identified at this site were limestone glade and dry upland forest. Because the forest is open and the glades are brushy, distinguishing between these was, and is, nearly impossible in much of the area. Forest trees are typical of dry limestone slopes in the Lesser Shawnee Hills: *Quercus prinoides*, *Q. stellata*, and *Juniperus virginiana*. This is also one of the few native sites for *Robinia pseudoacacia* in the state. The forest is open with an uneven canopy of limby trees. Limestone glades are dominated by *Andropogon scoparius* and *Sorghastrum nutans*. Common forbs include *Euphorbia corollata*, *Petalos-*

temon candidum, Lithospermum canescens, and *Physostegia virginiana.* These grasses and forbs are scattered throughout the forested part of the site.

Barker Bluff is part of the scarp face of the Spar Mountain Escarpment, a cuesta overlooking the Ohio River. The glades appear on the Shetlerville Limestone of the Mississippian System. These communities are similar to the limestone glades of Kentucky, Tennessee, and southern Indiana. The discovery of *Silphium trifoliatum* indicates the possibility that other southeastern glade species may be present.

The specimen (S. Olson; 25Sep86; #444) is deposited in the herbarium of the Illinois Natural History Survey, Champaign, Illinois (ILLS).

ACKNOWLEDGMENTS

I thank Max Hutchison, Dave Ketzner, Alice Long, and Mike Woods for confirmation of the species identity and/or reviewing this paper.

LITERATURE CITED

Fernald, M.L. 1950. Gray's manual of botany, eighth edition. American Book Company, Chicago. lxiv + 1632 pp.

Gleason, H.A. 1952. The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada, in three volumes. Hafner Press, New York.

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TRADE-OFFS AMONG COMPONENTS OF BAPTISIA LEUCANTHA (FABACEAE) REPRODUCTIVE YIELD IN RESPONSE TO SEED PREDATION

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ABSTRACT

A general hypothesis in plant ecology is that trade-offs in nutrient allocations among components of reproductive yield act to minimize losses in overall yield of an environmentally stressed plant. This hypothesis was tested using *Baptisia leucantha* as the study subject and the seed predator, *Apion rostrum*, as the environmental stress. Sticky Tanglefoot was applied to one group of plants to reduce *A. rostrum* predation in both 1985 and 1988. During both years Tanglefoot groups yielded higher grand mean counts of seeds/pod, pods/plant, and larger mean shoot sizes, as indicated by basal diameters, than control groups comprised of plants that were not treated with Tanglefoot. However, the control groups did show a heavier grand mean mass/seed. Grand mean mass/seed was also the least variable of the components of plant yield within all groups of both years. In 1988, pods that were aborted from a third group of plants had significantly fewer seeds than those not aborted, suggesting *B. leucantha* selectively aborts pods. *A. rostrum* affects the number of seeds/pod and therefore should also influence pod abortion. This accounts for the fewer pods matured by the control plants that were not treated with Tanglefoot. The higher grand mean mass/seed and invariability of the component, plus the selectivity in pod abortion, are evidence that trade-offs had occurred among the components which tended to buffer against decreases in total yield.

INTRODUCTION

A general hypothesis in plant ecology proposes that trade-offs in nutrient investments among components of reproductive yield act to minimize losses in

overall yield of an environmentally stressed plant (Janzen, 1977; Lee and Bazzaz, 1982; Primack and Antonovics, 1981; Stephenson, 1981; Stephenson and Winsor, 1986; Wilbur, 1977). The present study tests this hypothesis using a widely distributed legume in the Midwest, *Baptisia leucantha* T&G (Fabaceae)(Larisey, 1940) as the study subject, and as the environmental stress, the beetle *Apion rostrum* (Curculionidae) which is a seed predator of *B. leucantha* to the extent that it may consume over 5% of an annual seed crop (Haddock and Chaplin, 1982).

In Northeastern Illinois, where the study site is located, a seasonal cycle of growth by *B. leucantha* begins with new above-ground growth as the ground thaws in March. Flowering occurs from May to June with *Bombus* spp. being the major pollinator (Haddock and Chaplin, 1982; personal observation). New flowers appear as indeterminate racemes elongate. Racemes usually number one to two per plant, but may number as many as fourteen. By late June, the plants have reached their maximum height of 1 to 2m, flowering has about ceased, and pods have already formed. Many pods are aborted as the growing season progresses. Racemes may eventually bear over 200 mature pods. The cycle ends as seeds are dispersed by gravity when the pods dehisce from fall through the following spring.

A. rostrum begins its lifecycle within sealed pods of *B. leucantha* (Haddock and Chaplin, 1982). The beetle larvae emerge a few days after oviposition during June and consume developing seeds which are their only source of nutrition. Once reaching the adult stage, the beetles may stay within pods, or disperse as the pods dehisce, to overwinter (Haddock and Chaplin, 1982; personal observation). Come June, the adult *A. rostrum* re-emerge and oviposit into the pods of *B. leucantha*.

STUDY SITE

The study site was a restored 550m^2 tallgrass prairie plot located on the campus of the College of DuPage, DuPage County, IL. Restoration of the prairie began in the early 1970s. Today it is dominated by big bluestem (*Andropogon gerardi* Vitman) and Indiangrass (*Sorghastrum nutans* (L.)). Approximately 150 *B. leucantha* are scattered throughout the prairie. Mowed lawn, and a road carrying residential and college traffic lie north of the prairie. A marsh and an old field border the western and southern sides, while a forest is establishing on the eastern side. Mature *Acer saccharum* Marsh, *Maclura pomifera* Schneid, and *Juglans nigra* L., plus a weedy growth of young *Ulmus americana* L. and *Prunus virginiana* L., dominate the forest. The tallgrass prairie was burned in the fall of 1985 and the spring of 1986 during the course of this study.

MATERIALS AND METHODS

The components of *B. leucantha* reproductive yield studied were mass/seed, the number of seeds/pod, and the number of pods/plant. Plant size, as indicated by above ground biomass, was also considered since size can influence reproductive yield (Harper, 1977). The effects of seed predation on these four components were examined by reducing infestations with Tanglefoot (Tanglefoot Co. Grand Rapids, MI) in the DuPage Prairie. Tanglefoot is a sticky substance which reduced infestations of climbing insects on plants. A thin smear of Tanglefoot was applied around the bases of plants and all racemes, as well as around intermediate portions of all

racemes, of 11 and 18 randomly selected plants during June of 1985 and of 1988, respectively. Twenty and 25 randomly selected plants in 1985 and 1988, respectively, served as the untreated controls. A comparison of the number of pods/plant between the Tanglefoot and control treatments was done during late July of 1988. No significant difference ($p > 0.05$, Mann-Whitney test) in the number of pods/plant was found.

During October of both years, the number of pods/plant was counted on all of the then post-senescent plants. Then, five pods were sampled from each raceme: the most proximal pod, the most distal pod, and three spaced evenly between. If a raceme had less than five pods, all pods were removed.

Plant size was determined in the field by recording the basal diameters (BD) of plants at the first node. Preliminary analysis showed that BD has as significant positive relationship ($p < 0.05$; $t = 6.62$; $r^2 = 0.46$; $n = 53$; linear regression) to air-dried weight of senescent shoots in *B. leucantha*.

Pods taken from the field were left to air-dry at room temperature for one week. Then, the number of seeds/pod and the number of *A. rostrum*/pod were recorded. The latter measurement provided a measure of the effectiveness of Tanglefoot in reducing *A. rostrum* infestations of pods. Ten seeds from each pod were randomly selected and weighed to the nearest tenth of a milligram. If a pod contained less than ten seeds, all seeds were weighed. Comparisons of components of plant reproductive yield, plant size, and number of *A. rostrum*/pod were done using the Mann-Whitney test. Coefficients of variation (CV) were also computed from data to test which component (or components) were least variable. The *a priori* prediction was that if trade-offs occur, a component which benefits should also be the least variable since it is being buffered from the effects of seed predation.

Selective pod abortion can provide a means for nutritional trade-offs among components of reproductive yield to occur. For example, by nonrandomly aborting pods having fewer seeds, more seeds may be maintained than if pods were randomly aborted. To determine if pods having fewer seeds/pod are selectively aborted, comparisons were made between aborted pods and those not aborted. Because predation by *A. rostrum* affects seed numbers/pod and thereby possibly pod abortion, a similar comparison between pods was made considering counts of *A. rostrum*/pod. Between July 21 and 27, 1988, three pods if possible were randomly removed from all racemes of each of seven plants other than the 33 plants used in the seed predation experiment. If racemes had fewer than three pods, all pods were collected. Mean plant counts of seeds/pod and *A. rostrum*/pod from aborted pods found beneath each of the seven plants during the same time period were compared to those from pods that were removed using the Mann-Whitney test.

RESULTS

No herbivores and seed predators other than *A. rostrum* were observed feeding on *B. leucantha*. Trends between data from Tanglefoot and control treatments were similar (Table 1). Tanglefoot treated plants had lower grand mean numbers of *A. rostrum*/pod ($\bar{X}$ number $\cdot$ pod^{-1} $\cdot$ plant^{-1}) than control plants for both 1985 and 1988, although the difference was only significant ($p < 0.001$) during 1988 (See

Table 2 for all results of the Mann-Whitney tests). In relation, the grand mean numbers of seeds/plant ($\bar{X}$ numbers · pod^{-1} · plant^{-1}) from Tanglefoot treated plants were significantly higher during both years. Thus, Tanglefoot was effective in reducing seed predation. The mean numbers of pods/plant and BD's of plants were higher, while the grand mean masses/seed ($\bar{X}$ mg seed · pod^{-1} · plant^{-1}) were lower, in the Tanglefoot treatments compared with the control treatments. However again significant differences were only found for one of the two years for each type of comparison (Table 2). The rankings of the CVs that were computed from data in Table 1 were the same between treatments and years of the study: Mass/seed <BD< Seeds/pod<Pods/plant (Table 3).

Aborted pods contained significantly ($p < 0.001$) fewer seeds than pods not aborted ($U = 146$; $n_1 = n_2 = 7$; Table 4), thus providing evidence that *B. leucantha* selectively aborts pods. Nonsignificant ($p > 0.05$) differences were found in counts of *A. rostrum*/pod ($U = 32$; $n_1 = n_2 = 7$; Table 4).

DISCUSSION

Seed predation was the major factor causing differences in components of *B. leucantha* reproductive yield between control and Tanglefoot treatments. For the year 1988, it was possible that the significant difference in plant size between treatments existed from the beginning of the growing season and that this caused significant differences in the other plant components instead of predation. However if such conditions existed, mean counts of pods/plant measured early in the growing season should have been different between treatments. On the contrary, no significant difference was found. Also, no significant difference in BD's was noted between treatments in 1985, nonetheless trends in data between years were identical.

The overall impact of seed predation on components of reproductive yield was negative with less grand mean seeds/pod, pods/plant, and smaller BD's measured from the more heavily infested *B. leucantha* of the control treatments. However, there was evidence that trade-offs among components of *B. leucantha* reproductive yield may occur that buffer against losses to seed predation by *A. rostrum*. The relative consistency in grand mean mass/seed among plants and the contrasts in grand mean mass/seed between Tanglefoot treated plants and the control plants provided the evidence. Harper et al. (1970) state that the relatively low variability in mass/seed commonly observed among plants is due in part to stabilizing selection pressure for a mass great enough to support sufficient nutrition for successful seed germination and seedling survivorship. This can explain why grand mean mass/seed was relatively invariable between treatments and among plants within a treatment, while other components of reproductive yield, including basal diameters, were lower in the control treatment and always more variable. Mass/seed was maintained, and perhaps promoted, at the expense of other components of reproductive yield. Heavier mass/seed, as was experienced from the control treatments, has been shown to promote successful germination and seedling survivorship especially under shaded conditions such as would be found on the floor of a densely populated tall-grass prairie (Howe and Richter, 1982; Stanton, 1984; Winn, 1985). It is interesting to speculate whether *A. rostrum* might also promote the population growth of *B. leucantha* if it does affect mass/seed.

In addition, *A. rostrum* predation of seeds may affect seed abortion which in turn can account for the heavier mass/seed in the control treatments. The fact that pods are aborted as seeds develop, and apparently selectively so, suggests that other factors, such as nutrient limitations, may also limit reproductive yield. However, despite the nonsignificant difference in counts of *A. rostrum* /pod between aborted pods and those not aborted, seed predation should still affect seed number and therefore pod abortion. Seed predation's effect on pod abortion can explain why the control plants, which matured fewer pods, yielded heavier seeds. Nutrients could be reallocated from lost components of reproductive yield to those maintained.

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LITERATURE CITED

Haddock, R.C., and S.J. Chaplin. 1982. Pollination and seed production in two phenologically divergent prairie legumes (*Baptisia leucophaea* and *B. leucantha*). American Midland Naturalist 108:175-186.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, London.

Harper, J.L., P.H. Lovell, and K.G. Moore. 1970. The shapes and sizes of seeds. Annual Review of Ecology and Systematics 1:327-356.

Howe, H.F. and J. Smallwood. 1982. Ecology of seed dispersal. Annual Review of Ecology and Systematics 13:201-228.

Janzen, D.H. 1969. Seed eaters vs. seed size, number, toxicity, and dispersal. Evolution 23:1-27.

Larisey, M.M. 1940. A monograph of the genus *Baptisia*. Annals of the Missouri Botanical Gardens 27:119-244.

Lee, T.D. and F.A. Bazzaz. 1982. Regulation of fruit and seed production in an annual legume, *Cassia fasciculata*. Ecology 63:1363-1388.

Primack, R.B. and J. Antonovics. 1982. Experimental ecological genetics in *Plantago*. VII. Reproductive effort in populations of *P. lanceolata*. Evolution 36:742-752.

Stanton, M.C. 1984. Seed variation in wild radish: Effect of seed size on components of seedling and adult fitness. Ecology 65:1105-1112.

Stephenson, A.G. and J.A. Winsor. 1986. Lotus corniculatus regulates offspring quality through selective fruit abortion. Evolution 40:453-458.

Wilbur, H.M. 1977. Propagule size, number, and dispersion pattern in *Ambystoma* and *Asclepias*. American Naturalist 111:43-68.

Winn, A.A. 1985. The effects of seed size and microsite on seedling emergence in four populations of *Prunella vulgaris*. Journal of Ecology 73:831-840.

Table 1. Mean counts ±s of *Apion rostrum*/pod and components of *Baptisia leucantha* yield for the control (C) and Tanglefoot (T) treatments. Mass/seed, counts of *A. rostrum*/pod and seeds/pod are grand means ($\bar{X}$ • pod^{-1} • plant^{-1}) ±s.

Date (Treatment)	*Apion* pod	Mg mass/ seed	BD	Seeds/ pod	Pods/ plant
1985(C)	1.4 ±1.1	15.1 ±1.4	12.6 ±3.3	15.9 ±5.4	19.2 ±22.2
1985(T)	0.7 ±0.7	13.6 ±1.2	12.8 ±2.2	16.3 ±5.5	34.9 ±33.4
1988(C)	1.9 ±0.8	14.1 ±1.6	14.8 ±3.1	13.3 ±4.0	35.8 ±43.5
1988(T)	0.4 ±0.5	13.2 ±2.3	15.2 ±2.8	15.9 ±6.6	66.3 ±60.3

Table 2. Values of U by year from the Mann-Whitney tests between control and Tanglefoot treatments. The headings to the columns name the variables compared.

Year	*Apion*/ pod	Mg mass/ seed	BD	Seeds/ pod	Pods/ plant
1985	142	***190	128	*167	141
1988	***430	272	***411	**336	**332

*denotes significance: *p <0.05; **p <0.01; ***p <0.001.

Table 3. Variability (%CV) in the components of *Baptisia leucantha* yield according to year and treatment. (C) = Control treatment and (T) = Tanglefoot treatment.

Year (Treatment)	Mass/ seed	BD	Seeds/ pod	Pods/ plant
1985(C)	9.1	26.4	34.2	115.6
1985(T)	8.7	17.5	34.0	96.7
1988(C)	12.2	20.7	29.8	121.5
1988(T)	17.6	18.3	41.4	90.9

Table 4. Counts of seeds/pod and *Apion rostrum*/pod from aborted pods and pods not aborted. Data are expressed as grand means ($\bar{X}$ • pod^{-1} • plant^{-1}) ±s.

	Seeds/pod	*Apion*/pod
Aborted pods	18.4 ±3.1	1.0 ±0.4
Pods not aborted	22.4 ±3.3	1.1 ±0.5

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WOODY VEGETATION OF WARD WOODS, CUMBERLAND COUNTY, ILLINOIS

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ABSTRACT

The woody vegetation of sections of Ward Wood, Cumberland County, Illinois was surveyed in 1987. On a steep, east-facing hillside the present stand consists of 296 individuals per hectare. Sugar maple is the dominant species with an importance value of 132.6 (out of 300), is well represented in all diameter classes, and dominates the seedling and sapling categories. Other important species include hickories, hackberry, and slippery elm. In the poorly drained lowlands of this woods green ash dominates with an importance value of 76.4. Other important components include red maple, American elm, silver maple, cottonwood and hackberry.

INTRODUCTION

Ward Woods is a 10.1 hectare (25 acre) woodlot located in the Effingham Plain Section of the Southern Till Plain Division (Schwegman 1973), approximately five miles east of Greenup, Cumberland County, Illinois (NW 1/4, Sec 16, T9N R9E). The woodland was purchased by the Ward Family in the early 1900's. In the late 1950's, the larger black walnut trees were selectively lumbered, while during the mid-1960's, numerous large oaks were removed. These lumbering activities left large open areas in the forest canopy and disrupted the understory vegetation.

The topography of the woodlot varies from a small, nearly level upland in the western part, to a steep east-facing hillside through the middle of the woods with a slope that averages 30 degrees, while the eastern part is a flat poorly drained lowland bordering a small creek that enters the Embarras River about one-half mile away. Overall relief is about 20 m (66 ft.) with the high point 177 m (584 ft.) above sea level.

A survey of the woody vegetation of parts of this woodlot was conducted during the summer of 1987, to determine which woody species have invaded since the extensive disturbance in this woodlot during the 1950's and 1960's.

MATERIALS AND METHODS

A total of 24 quadrats, 25 m on a side (1½ ha), were located on the steep, east-facing hillside while 16 quadrats, 25 m on a side (1 ha), were located in the lowland part of the woods. In each quadrat the number, dbh, and species of all trees above 10 cm (4 inches) dbh were recorded for each tree. Relative frequency, relative dominance, relative density, and importance value (IV) of each species were then calculated for each of the two areas. The determination of the relative values follows McIntosh (1957) and Boggess (1964) in which the IV is the summation of the relative frequency, relative dominance, and relative density.

In each of the quadrats a .01 ha circular plot was randomly located. The saplings (2.5-10.0 cm dbh) were tallied on these plots and the frequency and density (individuals per ha) for each species determined for the east-facing hillside and the lowland. In conducting the woody seedling survey, eight 50 m transects were randomly located in the study area, six on the east-facing hillside and two in the flat lowland. Along each transect continuous 1 sq m quadrats were established and all seedlings (less than 2.5 cm dbh) counted and identified (Mohlenbrock 1975). From this data the seedling density (individuals per ha) and frequency was determined for each species for both areas.

RESULTS AND DISCUSSION

Hillside Forest: On the steep east-facing hillside a total of 20 woody species was recorded (Table 1), including 17 canopy trees and three understory trees. In this part of the woods *Acer saccharum* L. (sugar maple) had an IV of 132.6, far exceeding all other species. This species dominated all diameter classes, as well as the seedling and sapling categories. As indicated by its high relative frequency and relative density sugar maple was well distributed throughout the hillside, and a number of individuals exceeded 50 cm dbh.

The hickories (*Carya* spp.) as a species group were second with an IV of 47.1. Few hickory seedlings were encountered and no saplings were recorded, indicating that these species are not reproducing in this habitat. Most of the hickory seedlings found were of *C. cordiformis* (Wang.) K. Koch. Of the hickories, *C. ovata* (Mill.) K. Koch. dominated with an IV of 21.8, *C. cordiformis* had an IV of 11.6, followed by *C. tomentosa* (Poir.) Nutt., and *C. glabra* (Mill.) Sweet. *Celtis occidentalis* L. (hackberry) and *Ulmus rubra* Muhl. (slippery elm) ranked third and fourth in IV, respectively. These two species were well represented in the seedling category and the smaller diameter classes, while hackberry was also found in the 4-5 and 5+ cm diameter classes.

The oaks (*Quercus* spp.) were poorly represented in this part of the woods. *Quercus rubra* L. (red oak) was the only oak species recorded in the top eleven species in IV. Most oaks were in the 3 dm and higher diameter classes, and few oak seedlings and saplings were recorded.

Of the remaining species encountered on the steep east-facing hillside, none were common throughout the woods. Only a few *Juglans nigra* L. (black walnut) were recorded, since the larger individual of this species were removed about 35 years ago. All of the *Gymnocladus dioica* (L.) K. Koch. (Kentucky coffee tree) occurred near the base of the hillside, and in this area were a fairly important forest component.

Numerous forest surveys conducted during the past 25 years indicate that sugar maple is becoming an important component in the oak-hickory forests of central Illinois (Ebinger 1986a). Before European man settled in Illinois and altered the existing ecosystems, sugar maple was not an important species in central Illinois. A review of the General Land Office Survey notes reveals that only 23 individuals of sugar maples (out of a total of 1,627 witness trees) were recorded for Douglas (Ebinger 1987b) and Coles Counties (Ebinger 1987), the two counties just north of the study area. All of these sugar maples had been recorded from areas of dissected topography. It is quite possible that these dissected areas were protected from prairie fires by the terrain. When the pre-settlement IV's are combined and averaged, sugar maple had a pre-settlement IV of 3.0 (out of an IV of 200). This value is extremely low when compared to the average IV of the oaks (130.8 out of 200), and the hickories (29.8 out of 200).

The data from the present survey suggests that sugar maple is continuing to increase on the steep east-facing hillside in Ward's woods, dominating all diameter classes as well as the seedling and sapling categories. The opening of the canopy in this area by past cutting is probably responsible for this explosive increase. Runkle (1984) found that this aggressive species is able to rapidly fill tree-fall gaps. Also, this species grows rapidly, even in fairly small gaps, due to its ability to grow and form extensive root systems at low light levels (Logan 1965). Similar increases have been observed in other woods in east-central Illinois (Ebinger 1986a).

Lowland Forest: In the flat, poorly drained part of the woods a total of 21 woody species was recorded (Table 2), including of 19 canopy trees and two understory trees. In this part of the woods *Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern. (green ash) was the most important species with an IV of 76.4. This species is well represented in the smaller diameter classes, has some individuals in the larger diameter classes, averages 111 individuals per ha, and has a large number of seedlings per ha. Most of the seedlings were one and two year old plants that rarely exceeded 20 cm in height, and based on the few saplings found, few of the seedlings will probably survive.

Other common forest components with large numbers of seedlings were *Acer rubrum* L. (red maple), *Ulmus americana* L. (American elm), and hackberry which ranked second, third and sixth in IV, respectively. These three species had most individuals in the smaller diameter classes, relatively small average diameters, few saplings, and numerous seedlings. As with green ash, the seedlings of these three species were small, rarely exceeding 20 cm in height, and most probably will not survive to the sapling stage.

Acer saccharinum L. (silver maple), and *Populus deltoides* Marsh. (cottonwood), in contrast, were not represented in the seedling and sapling categories, had many individuals in the 5+ dm diameter class, and average diameters of 35 cm and 46 cm, respectively. The oak species encountered occurred mostly in the larger diameter classes, and were not represented in the seedling and sapling categories. All other woody species encountered in this lowland forest had IV's of less than 11, and were poorly represented in the seedling and sapling categories.

The data suggests that green ash, red maple, American elm, and hackberry will probably increase in importance in this lowland area. Since saplings and smaller diameter trees of these species are already established, they will enter the canopy as

veteran trees die. Silver maple and cottonwood, in contrast, are not reproducing, and will decrease in importance as the veteran trees die.

LITERATURE CITED

Boggess, W.R. 1964. Trelease Woods, Champaign County, Illinois: woody vegetation and stand composition. Trans. Ill. St. Acad. Sci. 57:261-271.

Ebinger, J.E. 1986a. Sugar maple, a management problem in Illinois forests? Trans. Ill. St. Acad. Sci. 79:25-30.

Ebinger, J.E. 1986b. Presettlement vegetation of Douglas County, Illinois. Erigenia 7:15-22.

Ebinger, J.E. 1987. Presettlement vegetation of Coles County Illinois. Trans. Ill. St. Acad. Sci. 80:15-24.

Logan, K.T. 1965. Growth of tree seedlings as affected by light intensity. I. White birch, yellow birch, sugar maple and silver maple. Dept. Forest Can. Publ. 1121.

McIntosh, R.P. 1957. The York Woods. A case history of forest succession in southern Wisconsin. Ecology 38:29-37.

Mohlenbrock, R.H. 1975. Guide to the vascular flora of Illinois. Southern Illinois University Press, Crbondale, xi+494 p.

Runkle, J.R. 1984. Development of woody vegetation in treefall gaps in a beech-sugar maple forest. Holarctic Ecology 7:157-164.

Schwegman, J. 1973. Comprehensive plan for the Illinois Nature Preserve System. Part 2. The natural divisions of Illinois. Illinois Nature Preserves Commission, Rockford, Illinois.

Table 1. Number of woody individuals per hectare by diameter classes, relative values, and average diameters for the leading dominants in a hillside forest, Cumberland County, Illinois.

	Seedlings		Saplings		Trees per hectare by diameter classes (dm)						Relative Values				Av.
Species	Den.	Freq.	Den.	Freq.	1-2	2-3	3-4	4-5	5+	Total	Rel. Freq.	Rel. Dom.	Rel. Den.	I.V.	Diam. (cm)
Sugar Maple	4933	33	333	79	65	30	24	24	15	158	20.0	59.0	53.6	132.6	27.6
Hickories*	167	2	—	—	8	14	11	3	1	37	21.8	12.5	12.8	47.1	27.7
Hackberry	2233	18	21	13	19	14	5	3	2	43	15.8	11.5	14.5	41.8	23.8
Slippery Elm	1867	8	17	13	13	3	1	—	—	17	12.5	2.3	5.7	20.5	17.9
Red Oak	100	1	4	4	—	—	1	1	3	5	5.8	4.9	1.6	12.3	51.5
Ky. Coffee Tree	133	1	13	4	4	6	1	1	—	12	5.8	2.6	3.9	12.3	23.4
Black Walnut	67	1	—	—	1	2	1	1	1	6	4.2	3.2	2.0	9.4	23.4
Green Ash	—	—	4	4	4	1	—	—	—	5	3.3	0.5	1.6	5.4	16.0
Others**	1632	—	87	—	8	1	1	1	2	13	10.8	3.5	4.3	18.6	22.7
Totals	11132		479		122	71	45	34	24	296	100.0	100.0	100.0	300.0	

*Includes *Carya cordiformis* (Wang.) K. Koch. (bitternut hickory), *C. glabra* (Mill.) Sweet. (pignut hickory), *C. ovata* (Mill.) K. Koch. (shagbark hickory), and *C. tomentosa* (Poir.) Nutt. (mockernut hickory).

**Includes *Acer negundo* L. (box elder), *Asimina triloba* (L.) Dunal. (pawpaw), *Cercis canadensis* L. (redbud), *Juglans nigra* L. (black walnut), *Quercus alba* L. (white oak), *Q. muhlenbergii* Engelm. (yellow chestnut oak), *Q. velutina* Lam. (black oak), *Tilia americana* L. (basswood), and *Ulmus americana* L. (American elm).

Table 2. Number of woody individuals per hectare by diameter classes, relative values, and average diameters for the leading dominants in a lowland forest, Cumberland County, Illinois.

	Seedlings		Saplings		Trees per hectare by diameter classes (dm)						Relative Values				Av.
Species	Den.	Freq.	Den.	Freq.	1-2	2-3	3-4	4-5	5+	Total	Rel. Freq.	Rel. Dom.	Rel. Den.	I.V.	Diam. (cm)
Green Ash	38100	66	150	38	38	40	20	9	4	111	13.9	28.6	33.9	76.4	25.6
Red Maple	94500	95	100	31	26	11	8	3	7	55	11.5	17.5	16.8	45.8	26.8
American Elm	1500	7	31	31	40	8	1	—	—	49	16.1	4.3	15.0	35.4	15.6
Silver Maple	—	—	—	—	11	4	2	2	7	26	8.1	16.5	8.0	32.6	35.5
Cottonwood	—	—	—	—	3	2	—	2	11	18	8.1	15.2	5.5	28.8	46.4
Hackberry	15200	69	25	25	14	5	3	3	—	25	10.3	5.4	7.7	23.4	22.8
Bitternut Hickory	—	—	—	—	8	2	1	—	—	11	5.7	1.6	3.4	10.7	20.3
Bur Oak	—	—	—	—	2	2	—	3	—	7	2.3	2.2	2.1	6.6	27.9
Others*	—	—	25	—	13	6	1	1	4	25	24.0	8.7	7.6	40.3	26.6
Totals	149300		331		155	80	36	23	33	327	100.0	100.0	100.0	300.0	

*Includes *Acer saccharum* Marsh. (sugar maple), *Asimina triloba* (L.) Dunal. (pawpaw), *Carya laciniosa* (Michx.) Loud. (kingnut hickory), *C. ovata* (Mill.) K. Koch. (shagbark hickory), *Cercis canadensis* L. (redbud), *Gymnocladus dioica* (L.) K. Koch. (Kentucky Coffee-tree), *Juglans nigra* L. (black walnut), *Platanus occidentalis* L. (sycamore), *Quercus bicolor* Willd. (swamp white oak), *Q. palustris* Muenchh. (pin oak), *Q. rubra* L. (red oak), *Salix nigra* Marsh. (black willow), and *Ulmus rubra* Muhl. (slippery elm).

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ASSOCIATION OF NITROMETHANE AND NITROETHANE IN SOME AROMATIC SOLVENTS

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ABSTRACT

A method is described for using a microcomputer to analyze dielectric constants of solutions of polar solutes as a function of concentration to evaluate dipole association constants. Details of the program and its use are presented and the results of computations for nitromethane and nitroethane in benzene, p-xylene, and mesitylene are reported. The dipole association constants are larger than expected for simple dipole association and may indicate interaction of these nitroalkanes in the aci form or the formation of multimers.

INTRODUCTION

The thermodynamics of self association of polar molecules in relatively inert solvents is of considerable interest and has been the subject of numerous investigations (Foster, 1973; Ginell, 1979; Yadava and Mauyra, 1986). This process can be represented as

$$2M \rightleftharpoons D$$

where M is a polar monomeric species and D is a dimer of that species. Although many studies of this type involve hydrogen bonded species (Foster, 1973 and Ginell, 1979) such systems will not be considered here. Experimental techniques employed include spectrophotometric, optical, nuclear magnetic resonance, calorimetric, and electrochemical methods. Many polar species are presumed to associate although precise measurements have not been carried out to determine thermodynamic equilibrium constants for the association.

Rather infrequently, the dielectric permittivity is used as a diagnostic measure of dipole association (Yadava and Mauyra, 1986; Basu and Ghosh, 1985; and Rossotti and Rossotti, 1961). This technique is based on the fact that the dielectric

permittivity (Σ) varies in a nonlinear way with increasing concentration of an associating polar solute. Thus, the analysis of these data enables calculations of association constants to be made (Kopecni, et al., 1981; House, 1984). Considering the fact that dielectric data are commonly determined, it is somewhat surprising that this technique is not used more often to determine association constants. Recently, Kopecni, Petkovic, and Laub have utilized this approach to study the association of N,N-disubstituted amides (Kopecni, et al., 1981). In the present study, we have utilized the dielectric data for solutions of nitromethane and nitroethane in aromatic solvents to investigate molecular association. Also, we present details of a computational procedure to use on a microcomputer to replace the procedure described as "tedious although straightforward" for determining association constants from dielectric data (Kopecni, et al., 1981).

METHODS

For a solution of two components, we can write

$$\Sigma = \bar{V}_1 C_1 \Sigma_1 + \bar{V}_2 C_2 \Sigma_2 \tag{1}$$

where C is a molar concentration, $\bar{V}$ is a molar volume, Σ is a dielectric permittivity, and the subscripts 1 and 2 refer to solvent and solute, respectively. Frequently, nonlinearity is observed which may be due to the dimerization reaction,

$$2M \rightleftharpoons D \tag{2}$$

where M is the monomeric species and D is a dimer. For this system, the dimerization constant can be written as

$$K = C_D / C_M^2 \tag{3}$$

Since solute monomer and dimer are both present, Eq. (1) becomes

$$\Sigma = \bar{V}_1 C_1 \Sigma_1 + \bar{V}_M C_M \Sigma_M + \bar{V}_D C_D \Sigma_D \tag{4}$$

Now it is apparent that

$$C_2 = C_M + 2C_D \tag{5}$$

so that

$$\Sigma - \bar{V}_1 C_1 \Sigma_1 - \bar{V}_M C_M \Sigma_M = (\bar{V}_D \Sigma_D - 2\bar{V}_M \Sigma_M) C_D \tag{6}$$

Solving Eq. (3) for C_D and substituting $C_M = C_2 - 2C_D$ leads to

$$C_D = g(K) = \left[\left(C_2 + \frac{1}{4K} \right) - \left(\frac{C_2}{2K} + \frac{1}{16K^2} \right)^{1/2} \right] \tag{7}$$

If we represent $\bar{V}\Sigma$ as f (an intensivity factor) we obtain

$$\Sigma - f_1 C_1 - f_M C_2 = \tfrac{1}{2}(f_D - 2f_M) \left[\left(C_2 + \frac{1}{4K} \right) - \left(\frac{C_2}{2K} + \frac{1}{16K^2} \right)^{1/2} \right] \tag{8}$$

from which K can be determined. In a previous method, this was done graphically by varying the value of K until a linear relationship was obtained for the two sides of Eq. (8). This "tedious though straightforward" method is replaced by a numerical procedure (House, 1984), but even this procedure can be very slow. In the present work, we have developed a microcomputer procedure to carry out the computations.

For a dilute solution where the concentration of dimer approaches zero, it can be shown that

$$\frac{\Sigma}{C_1} = f_1 + f_M \frac{C_2}{C_1} \tag{9}$$

Therefore, a plot of Σ/C_1 vs. C_2/C_1 yields the intensivity factor for the solvent as the intercept and that for the monomer, f_M, as the slope of the plot.

CALCULATIONS

Having determined the necessary input data from the published dielectric constants at various concentrations, the computation is initiated by performing linear regression using the two sides of Eq. (8) as variables. The initial trial value for K is 0.1 and the initial value for ΔK is 0.1. The value of the correlation coefficient is retained so that the next value of K, 0.2, can be used to see if a more nearly linear fit results. In the iterative process, $K_{i+1} = K_i + 0.1$. If incrementing K leads to an improved linear relationship, the process is repeated with the new correlation coefficient being retained as the test value. Linear regression is performed iteratively until K_i reaches a value where the linear regression results in a lower correlation coefficient. When this condition results, K_i is decremented by two incremental units, which is necessary to assure that K_i is reduced to a value lower than the optimal value. The value of the increment in K is reduced to 0.01 and the iterative linear regression is performed again until the test shows that a lower correlation coefficient is reached. If desired, the step refinement in the increment ΔK can be repeated to establish the value of K to greater accuracy. The refinement of ΔK can be carried out as many times as desired so that the desired number of step refinements (RS) must be specified at the beginning of the computation. If the initial increment in K is 0.1 ($\Delta K = 0.1$, given as DK in the program), the value of K is thus obtained to within $\pm (0.1)^{RS}$. For all practical purposes, there is no need to determine K to greater than three decimal places. A program listing in BASIC is given in the Appendix.

We have found that the calculated values for K are highly dependent on the values of f_1 and f_M. Accordingly, we have carried out numerical experimentation to evaluate this dependence.

DATA

The association of nitromethane and nitroethane in benzene, p-xylene, and mesitylene was studied using the recently published data of Yadava and Singh (1982). The dielectric constants were reported at 30°C for solutions in which the concentrations were given as weight fractions. However, if the densities of the solutions are known, the molarities can be calculated. The weight fraction of solute, W_2, is related to the molarity by

$$C = 1000\ \rho\ W_2/M_2 \tag{10}$$

where C is the molarity, W_2 is the weight fraction of solute, M_2 is the molecular weight of the solute, and ρ is the density of the solution. For the dilute solutions used, it is assumed that the density can be represented by

$$\rho = X_1\rho_1 + X_2\rho_2 \tag{11}$$

where ρ_1 and ρ_2 are the densities of the pure components and X_1 and X_2 are the mole fractions of the solvent and solute, respectively. Since the weight fraction of solute is the number of grams of solute divided by the number of grams of solution, we can write

$$X_2 = (W_2/M_2)/[(W_1/M_1) + (W_2/M_2)] \tag{12}$$

where M_1 and M_2 are the molecular weights of solvent and solute, respectively, and W_1 and W_2 are their weight fractions. Thus, using these procedures, it is possible to

calculate the molar concentrations C_1 and C_2 of Eq. (8) from the weight fractions given by Yadava and Singh (1982). This procedure has been used with the data published for systems of CH_3NO_2 and $C_2H_5NO_2$ in benzene, p-xylene, and mesitylene.

RESULTS AND DISCUSSION

The procedure described previously has been utilized with the data for N,N-dimethylacetamide (DMA) in hexane (Kopecni, et al.) and the nitro compounds in aromatic solvents (Yadava and Singh, 1982) to calculate the association constants. The results of these calculations are shown in Table 1. In the case of DMA in hexane, the results are identical to those obtained using the calculator program (House, 1984). For the nitro compounds, the K values are substantially greater than those expected for molecules which interact by dipole-dipole forces only (Treiner, et al., 1964). The reason for these large K values is not known. It may well be due to the formation of higher aggregates than dimers or the formation of dimers that are bound by forces other than dipole-dipole forces. For example, it is known that nitromethane can undergo transformation to an aci form (Millar and Springall, 1966), which can be shown as

$$CH_3NO_2 \rightleftharpoons CH_2 = N\begin{matrix}O\\ \diagdown\\ \diagup\\ OH\end{matrix} \tag{13}$$

Consequently, association of the aci form could proceed in much the same fashion as in the case of the carboxylic acids.

$$2\,CH_2 = N\begin{matrix}O\\ \diagdown\\ \diagup\\ OH\end{matrix} \rightleftharpoons CH_2 = N\begin{matrix}O\ldots HO\\ \diagdown\\ \diagup\\ OH\ldots O\end{matrix}N = CH_2 \tag{14}$$

It is possible that interaction in this way will lead to dielectric behavior that does not lend itself to the analysis by the method of Kopecni, Petkovic and Laub (1981).

In this work, f_1 and f_M were evaluated from the dielectric constants and molar volumes directly. This procedure does not lead to much difference for the f_1 value, but f_M, the intensivity of the monomer, is considerably different when evaluated this way compared to its evaluation by linear regression. We have found that the K values are dependent on the f_M value used in the calculations. This problem was not previously addressed (Kopecni, et al., 1981). Accordingly, the evaluation of K has been carried out using the data of Kopecni, et al., for MDA in hexane while varying f_M and f_1 from their reported values of 1.7921 and 0.2464, respectively. The results obtained are shown in Table 2, and they clearly indicate that the calculations are much more dependent on f_M than on f_1. This situation is so severe, in fact, that unless one is reasonably sure of the f_M value, little confidence can be placed in the calculated value of K.

We have also carried out calculations to determine the magnitude of the effects caused by variations in the f_M values used for the nitromethane and nitroethane. Table 3 shows the results of these calculations. It should be noted here that the

variations in f_M are larger than those tested for the case of DMA in hexane. The intent here was to determine what would be the resulting error in K if f_M is substantially in error. It is unlikely that the f_M values are actually in error by amounts anything like this large. Smaller errors than those tested are reasonable so the magnitudes of the dimerization constants are probably correct.

The explanation for the trends in K values is not straightforward. There are at least three separate factors to consider. These are the energy of the interaction of the nitroalkane molecules with each other, the solvation enthalpy of the monomers, and the solvation enthalpy of the dimers. Except for the K for CH_3NO_2 association in benzene, the association constants appear to increase in a general way with the addition of methyl groups to the aromatic ring. It is not clear which of the enthalpies described above is responsible for this effect.

While questions and uncertainties still remain, this work has shown that the dimerization of nitroalkanes can be studied by means of dielectric constants of dilute solutions. It has also demonstrated the nature of the errors that can result in the calculated K when the intensitivity factors for the monomer and solvent are in error. While hydrogen bonding or the formation of multimers may be responsible for the unexpectedly large values for the association constants, the results should be correct as far as trends are concerned. We are also performing molecular orbital calculations to determine configurational energies for the nitro and aci forms of nitromethane to try to determine some estimation of the relative amounts of these forms in the gas phase of nitroalkanes.

LITERATURE CITED

Basu, R., and M. Ghosh, Indian J. Chem., *24A*, 227 (1985).
Foster, R., Molecular Complexes, Vol. I and II, Crane, Russak, & Co., New York, 1973.
Ginell, R., Association Theory, Elsevier, Amsterdam, 1979.
House, J.E. Jr., Comput. Chem., *8*, 123 (1984).
Kopecni, M.M., R. Laub, and Dj. M. Petkovic, J. Phys. Chem., *85*, 1595 (1981).
Millar, I.T., and H.D. Springall, Sidgwick's Organic Chemistry of Nitrogen, 3rd ed., Oxford, 363 (1966).
Rossotti, F. and H. Rossotti, Determination of Stability Constants, McGraw-Hill, New York, 318 (1961).
Treiner, C., J.F. Skinner, and R.M. Fuoss, J. Phys. Chem., *68*, 3406 (1964).
Yadava, R.R., and S.R. Mauyra, Indian J. Chem., *25A*, 460 (1986).
Yadava, R.R., and V.N. Singh, Indian J. Chem., *21A*, 17 (1982).

APPENDIX

A program is given here to perform the calculation of dipole association constants by the method described by Kopecni, et al. [6]. The program listed is the simplest version in which the concentrations and dielectric constants are input manually. In the program listing, CS is the concentration of the solvent, CA is the concentration of the solute, E is the dielectric constant, and KD is the association constant. These concentration symbols follow the original terminology of Kopecni, et al. [6] and allow for numerical subscripting without confusion. The initial value of KD is taken to be 0.1 as is the increment DK. The number of specified step refinements (RS) to be carried out on DK is given as three in step 90 of the program, but this and the starting values for KD and DK can be changed as desired. As presented, the computation can handle as many as 30 data points, and the number used must be specified at the beginning of the run. Linear regression is performed iteratively until a trial value of KD gives a lower correlation coefficient and then the KD value is decremented and step refinement occurs. Thus, KD is eventually found to within $\pm (0.1)^{RS}$ where RS is the number of step refinements that occur.

```
10 PRINT "DIPOLE ASSOCIATION — HOUSE AND KEMPER"
20 DIM E(30)
21 DIM CS(30)
22 DIM CA(30)
25 DIM X(30)
26 DIM Y(30)
30 PRINT "# OF DATA PAIRS?"
35 INPUT P
40 PRINT "FM="
45 INPUT FM
50 PRINT "FS="
55 INPUT FS
80 KD=0.1
85 DK=0.1
90 RS=3
95 Q=0
100 FOR U=1 TO P
110 PRINT "CS";U;"="
115 INPUT CS(U)
120 PRINT "CA";U;"="
125 INPUT CA(U)
130 PRINT "E";U;"="
135 INPUT E(U)
140 NEXT U
150 J=0
151 K=0
152 L=0
153 M=0
154 R2=0
155 B=0
156 A=0
```

```
157 FOR Z=1 TO P
160 Y(Z)=E(Z)-FS*CS(Z)-FM*CA(Z)
170 X(Z) =(CA(Z)+1/(4*KD))-SQR((CA(Z)/(2*KD))+(1/(16*(KD^ 2))))
180 J=J+X(Z)
190 K=K+Y(Z)
200 L=L+X(Z)^ 2
210 M=M+Y(Z)^ 2
220 R2=R2+X(Z)*Y(Z)
230 NEXT Z
240 B=(P*R2-K*J)/(P*L-J^ 2)
250 A=(K-B*J)/P
260 J=B*(R2-J*K/P)
270 M=M-K^ 2/P
280 K=M-J
290 R2=J/M
300 R=SQR(R2)
310 PRINT "KD=";KD
320 PRINT "R=";R
330 PRINT
335 R1=ABS(R)
340 IF R1>Q THEN 400
350 KD=KD-2*DK
355 Q=0
360 DK=DK*0.1
365 KD=KD+2*DK
370 RS=RS-1
380 IF RS=O THEN 999
390 GOTO 150
400 KD=KD+DK
410 Q=R1
415 GOTO 150
999 END
```

Table 1. Calculated dimerization constants.

Solute	Solvent	f_M	f_1	K	Corr. Coef.
DMA[+]	Hexane	1.7291	0.2464	0.184	0.97847
CH_3NO_2	Benzene	1.9487	0.2038	10.40	0.96561
CH_3NO_2	*p*-Xylene	1.9487	0.2806	9.18	0.97739
CH_3NO_2	Mesitylene	1.9487	0.3185	26.80	0.99632
$C_2H_5NO_2$	Benzene	2.0159	0.2038	4.88	0.99492
$C_2H_5NO_2$	*p*-Xylene	2.0159	0.2806	7.87	0.99499
$C_2H_5NO_2$	Mesitylene	2.0159	0.3185	274.50	0.99122

[+]N,N-Dimethylacetamide; data from Ref. [6].

Table 2. Effects of the f_M and f_1 values on the calculated association constants for DMA.[+]

f_1	f_M	K	Corr. Coef.
0.2464	1.60	0.547	0.98817
0.2464	1.65	0.389	0.98539
0.2464	1.68	0.305	0.98322
0.2464	1.70	0.253	0.98150
0.2464	1.7291	0.184	0.97847
0.2464	1.74	0.160	0.97714
0.2464	1.76	0.118	0.97437
0.2464	1.80	0.046	0.96710
0.2464	1.84	0.013	0.95618
0.20	1.7291	0.113	0.97401
0.21	1.7291	0.127	0.97501
0.23	1.7291	0.158	0.97703
0.24	1.7291	0.174	0.97793
0.2464	1.7291	0.184	0.97847
0.25	1.7291	0.190	0.97877
0.26	1.7291	0.207	0.97956
0.28	1.7291	0.242	0.98102
0.30	1.7291	0.279	0.98233

[+]The correct values are $f_M = 1.7291$ and $f_1 = 0.2464$

Table 3. Effects of f_M values on calculated association constants.

System	f_M	K	Corr. Coef.
$C_2H_5NO_2$ in *p*-xylene[+]	1.75	1.138	0.95200
	2.00	7.277	0.99453
	2.25	19.573	0.99904
CH_3NO_2 in *p*-xylene[+]	1.50	0.013	0.57420
	1.75	3.542	0.94321
	2.00	10.959	0.98119
	2.25	21.899	0.99087
$C_2H_5NO_2$ in benzene[++]	1.75	0.290	0.91337
	2.00	4.459	0.99432
	2.25	12.815	0.99842
$C_2H_5NO_2$ in mesitylene[+++]	1.75	56.946	0.93044
	2.00	256.470	0.99048

[+]Using $f_1 = 0.28060$
[++]Using $f_1 = 0.20490$
[+++]Using $f_1 = 0.31906$

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ON THE LINGUISTIC SIGNIFICANCE OF THE METAGRAMMAR IN TWO-LEVEL MODELS OF NATURAL LANGUAGE

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ABSTRACT

The metavariables of two-level grammars used to model natural language have generally served as *ad hoc* features needed to avoid transformations in parsing and generation. Here it is suggested that the metavariables can serve to encode the communicative function of a string in the language accepted by the grammar. This encoding can direct a mapping from a sentence in one natural language to its functional equivalent in another natural language. The process is exemplified in the context of automatic translation from Mandarin Chinese into English.

1. Introduction.

Two-level models of natural language have been under development since 1982 by Krulee (1985, 1987) and his students (Rager 1987, Larson 1987, Rauff 1988). Initially, the metagrammars of these two-level models served primarily as parsing devices, allowing rather problematic syntax, generally English, to be conveniently parsed by augmented transition networks. In this paper, I suggest that the metagrammar may have a linguistic counterpart. Recognition of this counterpart and its development could lead to two-level models that pay more attention to the semantics and pragmatics of natural language. More significantly, this linguistic counterpart is already receiving serious research attention by linguists involved in the teaching of foreign languages. The two-level approach to natural language processing then may be shown to offer a bridge between applied linguistics and computational linguistics.

I begin with a discussion of two-level grammars.

2. Two-level grammars.

Two-level grammars were first used in the development of the programming

language Algol 68 (see Van Wijngaarden 1976). A two-level grammar consists of two interacting formal grammars. In the protogrammar, certain constituents are independently derived by means of rules in the metagrammar. For example, consider the grammar G_1 (due to Krulee 1985):

metagrammar:

N ---> X | XN

protogrammar:

S ---> bn | bNS
X ---> a

The derivation of a string in G_1 begins with the S-production in the protogrammar. The presence of the **meta**variable N causes a shift of control to the metagrammar. When the derivation of a string in the metagrammar is completed, that string is substituted for N in the protogrammar, and the **proto**-derivation is continued. Once an assignment to a metavariable is completed, it may not be changed for the duration of the derivation. This requirement is called the **principle of uniform replacement.** A sample derivation is shown in detail below. The following notation is used:

===> indicates a one step derivation in the protogrammar.
===>> indicates a one step derivation in the metagrammar.
~~~ indicates a transfer of control from one grammar to the other.

Derivation of a string in $L(G_1)$:

S ===> bNS ~~~ N ===>> XN ===>> XXN ===>> XXX ~~~ bXXXS ===> baXXS ===> baaXS ===> baaaS ===> baaabN ~~~ N is XXX ~~~ baaabXXX ===> baaabaXX ===> baaabaaX ===> baaabaaa.

It is clear that $L(G_1) = \{ (ba^k)\ (ba^k)^* : k \geq 1 \}$.

The metagrammar enables a two-level grammar to generate rather complex languages with relatively simple rules. Indeed, it is possible to write two-level grammars with context-free components which generate some context-sensitive languages (Greibach (1974) has investigated the generative power of two-level grammars under various restrictions on the meta- and proto-grammars).

For example, the well-known context-sensitive language $L_1 = \{a^n b^n c^n : n \geq 1\}$ can be generated by the two-level grammar G_2.

G_2:

metagrammar:

X ---> IX | I

protogrammar:

S ---> A<X> B<X> C<X>
A<IK> ---> A<I>A<K>
B<IK> ---> B<I>B<K>
C<IK> ---> C<I>C<K>
A<I> ---> a
B<I> ---> b
C<I> ---> c

Here, the variables A<X>, B<X>, etc. bear the funny bracket extensions to denote reference to the metagrammar. Also, the recursive rules which begin with A<IK>, B<IK>, and C<IK> are actually shorthand for a large set of rules and potential rules. A sample derivation will illustrate how G_2 operates.
~~~

S===> A<X> B<X> C<X> ~~~ X===>> IX===>> II ~~~
A<II> B<II>C<II> ===> A<I>A<I>B<II>C<II>===> a A<I>B<II>C<II>
===> aaB<II>C<II> ===> aaB<I>B<I>C<II> ===>aabB<I>C<II> ===>
aabbC<II> ===> aabbC<I>C<I> ===> aabbcC<I> ===> aabbcc.

It should be clear that $L(G_2) = L_1$.

3. Two-level grammars and natural language processing.

Krulee (1985) has shown how the strategic use of two-level grammars in natural language processing can eliminate the need for transformations in a formal grammar of a natural language (English). In this respect, his work aims at the same goal as Gazdar's **Phrase Structure Grammar** (Gazdar and Pullum 1982), namely, the elimination of transformations. As an example of how Krulee can model natural language with two-level grammars, consider the grammar G_3 (adapted from Krulee 1985:31-32), which generates English yes/no questions.

G_3:

metagrammar:

Type ---> Decl | Ques

protogrammar:

S ---> X<Type> VP
VP ---> Verb NP2
NP2 ---> Det Noun
NP ---> Det Noun
X<Decl> ---> NP
X<Ques> ---> Aux NP

In this example, I have omitted the parts of Krulee's grammar which control number agreement and verb tenses. If we take these controls as given, then G_3 can generate sentences like

(1) The boy ate the carrots.
(2) Did the boy eat the carrots?

In both cases, the protogrammar relinquishes control to the metagrammar early in the derivation in order to determine the primary function (interrogative or declarative) of the sentence to be generated. The derivation of (2) is shown here:

S===>X<TYPE>VP~~~ TYPE===>>QUES~~~ X<Ques>VP===>Aux NP VP
===>Did NP VP===>Did Det Noun VP===>Did the Noun VP===>Did the boy
VP===>Did the boy Verb NP2===>Did the boy eat NP2===>Did the boy eat Det
Noun ===>Did the boy eat the Noun ===>Did the boy eat the carrots?

Krulee writes that the metagrammar's "primary function is to select among declaratives vs. interrogatives . . ." (Krulee 1985:31). However, it is clear from his choice of names for the metavariables that he attaches no linguistic significance to these metavariables. Yet, the selection of "declarative vs. interrogative" is certainly a linguistic choice made in the utterance of the sentence.

This choice must be made in any natural language. It is therefore not unreasonable to expect to see certain similarities in the metavariables of two-level grammars of a variety of languages. The question which then arises concerns the number and nature of these common metavariables. That is, besides making statements and asking questions, what other functional choices are made in uttering a sentence in any natural language?

4. Functional-notionalism.

A preliminary answer to the question posed in the last paragraph has come from a surprising (for computational linguistics) source, foreign language teaching research.

In an influential work, Van Ek and Alexander (1980) specify the learning objectives for students of a foreign language. These objectives not only enumerate what is needed in the learning of a foreign language, but also suggest some fundamental aspects of language when it is viewed as a communicative skill.

Van Ek and Alexander's objectives (1980:7-9) address the following components:

1. the situation in which the language is to be used,
2. the language activities in which the learner will participate,
3. the language **functions** which the learner will fulfill,
4. the general and specific language **notions** which the learner will be able to handle,
5. the language **forms** which the learner will be able to use, and
6. the degree of skill with which the learner performs these language tasks.

As an example of these components consider the language skills a student needs for asking a question in an algebra class. The situational requirements include the topic at hand, let's say finding the roots of polynomials, the respective roles of student and teacher, and the degree of formality in the classroom. The student's activities include formulating and asking the question, determining whether or not the question has been answered, and understanding the response. The language function to be performed is that of asking a question. The notions involved could include sequence ("Do we always look for the rational roots first?), or temporality (Could you explain why 6 is not a root, **again**?) and specific notions like **root, polynomial, factor, coefficient,** etc. The language forms encompass the proper syntax for the desired function. In this situation, the forms include sentence initial auxiliary verb constructions (Do we . . .?), Question-word constructions (Why . . .?), etc. Finally, the level of skill with which the question is posed is probably proportional to the effectiveness of the question in eliciting a useful response. (Contrast "I don't get why you do that to those things?" To "Why did you divide every coefficient by 2?")

Viewing language learning as learning the appropriate forms and notions to carry out particular functions in specified situations has gained wide popularity among teachers of foreign languages and teachers of English as a second language (Finocchiaro and Brumfit 1979) and has been adopted as a paradigm for ESL textbooks (Zaffran, et al. 1988). For computational linguistics, this **functional-notional** approach to language learning provides a mechanism for constructing a formalism that recognizes language as communication.

5. Functional-notionalism and two-level grammars.

In combining the pedagogy of the functional-notional approach with the formalism of two-level grammars, we are implicitly adopting the idea that the form of language is in some way at least partially determined by the function it is intended to perform. The notion that linguistic form and linguistic function are interrelated is by no means new. Indeed, it has been a persistent topic of linguistic discussion (see Robins 1979, or Dinneen 1967). Most recently, the most detailed

investigation of the "complex interaction of form and function in language" has been undertaken by Foley and Van Valin (1984), Silverstein (1981), and Halliday (1979). It is not the aim of this paper to get involved too deeply in the linguistic arguments revolving about form and function. Rather, I am concerned with the formal generative implications of the discussion.

If we acknowledge that, at least some linguistic forms follow from the linguistic function they are intended to perform, then it is not a great leap to postulate that perhaps a generative grammar of a language could be constructed at two levels. A **meta**grammar would generate the specific functions which a string is intended to perform, and then these functions would direct the operation of a **proto**grammar which would generate the specific linguistic entity required to perform those functions.

The two-level model (G_3) of the small fragment of English shown in section 3 adopts this premise. A larger two-level grammar built along the same principles would follow a careful analysis of form and function in a specific natural language. Although a complete grammar along these lines does not exist for any language (see Langendoen and Postal (1986) for an interesting argument denying that such a grammar is even theoretically possible), we can find partial analyses in language texts that adopt some version of functional-notionalism. In these texts a student is given the appropriate language **form**s needed to perform certain language **functions.**

As an example of this consider DeFrancis' *Beginning Chinese* (1976). DeFrancis presents numerous "patterns" which are appropriate for fulfilling different functions. These include, asking a yes/no question, talking about the existence of something at a place, asking for and giving directional information, expressing purpose, etc. Rauff (1988) has taken 24 of these linguistic functions and their Chinese forms and constructed a two-level grammar based upon the principles outlined in this paper. Rauff's two-level grammar of Chinese (Rauff 1988:130-138) can generate the Chinese sentences given in the first 9 lessons of DeFrancis' text.

6. Application to machine translation.

One rather obvious application of the two-level functional-notional approach to modeling natural language is automatic translation between natural languages. Under the approach outlined in this paper, a translation of a sentence S_L in language L to an equivalent sentence S_M in language M would involve the following steps:

T1: Parse S_L and record the function and the specific notions.

T2: Generate the appropriate general form and specific notions in S_M necessary to perform the function determined in T1.

If we accept that an "equivalent" sentence exists in the target language (see Katz 1981), then the problem becomes one of determining the function of a string from its form. This is by no means a trivial problem! Questions of pragmatics enter into the discussion rather quickly as we try to deduce the intended function of "Can you reach the salt?" from its form. A great deal of linguistic research has been expended on the relationship between language form and language function (see Foley and Van Valin 1984, and Levinson 1984). However, in many cases the communicative function of a sentence is retrievable from its syntax. In these cases the ability to determine the function may be computationally exploited.

As an example, the appendix gives some sample output of the translating program FTL (Rauff 1988) which uses the translating scheme described above and

two-level functional grammars of Chinese and English. (The numeral suffixes on the Chinese lexical items denote tones.) The Chinese sentence "Talmen zai4 zher4 mai4 shen2mo", for example, is parsed by the two-level Chinese grammar in FTL. The parsing determines that the function of the sentence is a **WHAT-question,** and the notions include selling objects in a deictically referenced place. The English two-level generator then takes these functions and notions and produces the English string "What do they sell here?".

The basic process of the translating program is as follows. The two level-parser operates on an elementary augmented transition network that determines the function of the sentence from the syntax. The functions are derived from the Chinese "patterns" given in DeFrancis' (1976) beginning Chinese text. After the parse, the Chinese lexical items are mapped into English using an annotated Chinese-English dictionary. These English items are then passed, along with the sentential function, to an English two-level generator (also based on an augmented transition network). The English sentence is then produced according to the English grammar directed by the appropriate assignments of function in the metagrammar.

The use of communicative function is not the only approach to machine translation possible. Other systems are totally syntactic or rely on some sort of semantic representation of the input string (see Slocum (1985) for a survey of machine translation). However, the use of a metagrammar in a two-level grammar to model the communicative function of a sentence offers a new, perhaps more natural approach, to automatic translation.

7. Summary.

I have argued that the metagrammar of a two-level model of natural language may be used to control the linguistic function of a string being generated by the grammar. This type of modeling requires that some definite relationships between linguistic form and linguistic function be established. These relationships are most clearly spelled out in the pedagogy of functional-notionalism. One application of this approach to natural language processing is that of functional machine translation.

LITERATURE CITED

DeFrancis, J. 1976. Beginning Chinese. Yale University Press, New Haven.

Dineen, F.P. 1967. An Introduction to General Linguistics. Georgetown University Press, Washington, D.C.

Finocchiaro, M., and C. Brumfit. 1979. The Functional-Notional Approach. Oxford University Press, Oxford.

Foley, W.A., and R.D. Van Valin. 1984. Functional Syntax and Universal Grammar. Cambridge University Press, Cambridge.

Griebach, S.A. 1974. Some restrictions on W-grammars. Proceedings of the Annual ACM Symposium on the Theory of Computing: 256-65.

Gazdar, G., and G.K. Pullum. 1982. Generalized Phrase Structure Grammar. Indiana University Linguistics Club, Bloomington.

Halliday, M.A.K. 1979. Explorations in the Function of Language. North-Holland, Amsterdam.

Katz, J. 1981. Language and Other Abstract Objects. Blackwell, Oxford.

Krulee, G.K. 1987. Two-Level Processing of Natural Language. Indiana University Linguistics Club, Bloomington.

Krulee, G.K. 1985. Two-Level Representations of Natural Language. Indiana University Linguistics Club, Bloomington.

Larson, T.J. 1987. Semantics for coordinated substitution grammars as implemented in Prolog. Ph.D. dissertation, Northwestern University.
Levinson, S.C. 1984. Pragmatics. Cambridge University Press, Cambridge.
Rager, J.E. III. 1987. Multi-level Structures for Natural Language Processing. Ph.D. dissertation, Northwestern University.
Rauff, J.V. 1988. Machine Translation with Two-Level Grammars. Ph.D. dissertation, Northwestern University.
Robins, R.H. 1979. A Short History of Linguistics. Longman, London.
Silverstein, M. 1981. Case marking and the nature of language. Australian Journal of Linguistics 1:227-246.
Slocum, J. 1985. A survey of machine translation: its history, current status, and future prospects. Computational Linguistics 11:1-17.
Van Ek, J.A., and L.G. Alexander. 1980. Threshold Level English. Pergamon Press, Oxford.
Van Wijngaarden, A. et. al. (Eds). 1976. Revised Report of the Algorithmic Language ALGOL 68. Springer-Verlag, Berlin.
Zaffran, B., D. Krulik, and M. Scheraga. 1988. Hello, English. National Textbook Company, Lincolnwood, IL.

SAMPLE OUTPUT OF FTL

This appendix contains several examples of the output produced by the functional two-level translator, FTL. For each sample, the Chinese input sentence is given with the translation produced by FTL immediately below. The parentheses are present because the input and output sentences are both LISP expressions.

(WO3 BU HUI4 SHUO1 ZHONG1GUO-HUA4)
(I CAN NOT SPEAK CHINESE)

(CHENG2 LI3 TOU DE SHAN1 DOU1 HEN3 XIA03)
(THE MOUNTAINS INSIDE THE CITY ARE ALL VERY SMALL)

(TU2SHU1GUAN3 JIN1TIAN MEI2 YOU3 REN2 KAN4SHU1)
(THERE ARE NOT ANY PEOPLE READING IN THE LIBRARY TODAY)

(GAO1 TAI4TAI YOU3 PENG2YOU CONG2 MEI3GUO DAO4 ZHONG1-GUO LAI2 MA)
(DOES MRS GAO HAVE A FRIEND COMING FROM AMERICA TO CHINA?)

(TA1MEN AZI4 ZHER4 MAI4 SHEN2MO)
(WHAT DO THEY SELL HERE?)

(WO3 BU ZHI1DAO4 SHI ZAI4 JIA1 NIAN4SHU1 HAO3 HAI2SHI ZAI4 TU2SHU1GUAN3 NIAN4SHU1 HAO3)
(I DO NOT KNOW IF IT IS BETTER TO STUDY AT HOME OR STUDY AT THE LIBRARY)

(WO3 BU XIANG3 ZAI4 NER4 MAI3 SHU1)
(I DO NOT PLAN TO BUY A BOOK THERE)

(TA1 BU XIANG3 ZAI4 SHU1DIAN4 MAI3 SHU1)
(HE DOES NOT PLAN TO BUY A BOOK AT THE BOOKSTORE)

(WO3 MING2TIAN QU4 MAI3 MAO2BI3)
(I WILL GO TO BUY A WRITING BRUSH TOMORROW)

(HUO4ZHE3 WO3 MING2TIAN QU4)
(PERHAPS I WILL GO TOMORROW)

(NI3 ZHAO3 SHEN2MO)
(WHAT DO YOU LOOK FOR?)

(˙ZUO3 BIAR1 DE FANG2ZI LI2 YOU4 BIAR1 DE FANG2ZI DUO2MO YUAN4)
(HOW FAR IS THE HOUSE ON THE LEFT FROM THE HOUSE ON THE RIGHT?)

(MAO2BI3 ZAI4 ZHER4 MA)
(IS THE WRITING BRUSH HERE?)

(TA1 DE FANG2ZI ZAI4 SHAN1 SHANG4)
(HIS HOUSE IS ON THE MOUNTAIN)

(ZHONG1GUO-FAN4 HAO3 CHI1)
(CHINESE FOOD IS GOOD TO EAT)

(ZHEI4 BEN3 SHU1 RONG2YI NIAN4)
(THIS BOOK IS EASY TO READ)

(NEI4 GE GONG1YUAN2 HEN3 DA4)
(THAT PARK IS VERY BIG)

(TA1 XI3HUAN NEI4 GE SHU1)
(HE LIKES THAT BOOK)

(WO3 DE FANG2ZI ZAI4 NEI4 GE SHAN1 SHANG4)
(MY HOUSE IS ON THAT MOUNTAIN)

(WO3 DE FANG2ZI ZAI4 TA1 DE SHAN1 SHANG4)
(MY HOUSE IS ON HIS MOUNTAIN)

(NI3 HUI4 BU HUI4 SHUO1 ZHONG1GUO-HUA4)
(CAN YOU SPEAK CHINESE?)

(TA1 SHI4 YING1GUO-REN2)
(HE IS ENGLISH)

(GAO1 TAI4TAI YE3 SHI4 YING1GUO-REN2 MA)
(IS MRS GAO ALSO ENGLISH?)

(TA1MEN DOU1 HUI4 SHUO1 ZHONG1GUO-HUA4)
(THEY ALL SPEAK CHINESE)

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ORIGIN OF PYRITE NODULES IN THE ST. PETER SANDSTONE, BUFFALO ROCK STATE PARK, ILLINOIS

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ABSTRACT

Pyrite nodules occur in the top of the Ordovician St. Peter Sandstone, directly beneath the unconformity with the overlying Pennsylvanian Colchester (No. 2) Coal at Buffalo Rock State Park. The pyrite formed as a result of the anoxic conditions produced by the Pennsylvanian coal swamp or by the coalification processes that would have expelled anoxic water into the permeable St. Peter substrate. The nodules are not present where units other than the coal overlie the St. Peter. The nodules are concentrations of pyrite that cement quartz grains in the sandstone and replace some of the earlier calcite and quartz cement. Localization of the nodules was controlled by bedding and cross-bedding planes and by irregular vertical joints. Many of the nodules are surrounded by bleached rims of gypsum cement and by very dark bands of limonite, both of which are the result of oxidation.

INTRODUCTION

Nodules of pyrite occur in the exposed top of the Ordovician St. Peter Sandstone at Buffalo Rock State Park. The pyrite serves as a localized cement that binds the quartz grains of the sandstone. Although pyrite is abundant in Illinois coal beds and in associated organic-rich clays and shales, it is uncommon for it to be found in the clean, quartz sandstone of the St. Peter Formation. The purpose of this paper is to describe this unusual occurrence of the pyrite at Buffalo Rock and to offer an explanation for its presence.

A number of geologists have described the St. Peter Formation in the LaSalle area and/or in Illinois (Cady, 1919; Willman and Payne, 1942; Odum et al., 1962; Templeton and Willman, 1963; Reinertsen and Killey, 1971; and Willman et al., 1975). The only mention of pyrite in the St. Peter is by Willman and Payne (1942,

p.72), where they say that pyrite is locally present and is "abundant enough to form dark-colored streaks which accentuate the bedding-planes and to cement the sand grains into hard clusters." No further descriptions are given, nor are any geographic or stratigraphic locations.

Buffalo Rock State Park is located along the Illinois River about ten miles east of LaSalle and about five miles west of Ottawa, LaSalle County. Buffalo Rock itself is a large, steep-sided monolith of St. Peter sandstone, unconformably overlain by Pennsylvanian rocks, that rises 30-37 meters (100-120 feet) above the floodplain of the Illinois River. It was at one time an island in the river and its top is approximately at the same level as the tops of the bluffs on either side of the river. All but the east end of Buffalo Rock was strip mined for coal between 1950 and 1952. It is the stripping that exposed the surface of the St. Peter and the contained pyrite nodules. Surface reclamation is currently under way.

Structurally Buffalo Rock is situated approximately on the crest of the LaSalle anticline.

MATERIALS AND METHODS

Field examination of Buffalo Rock and adjacent areas was undertaken intermittently from the summer of 1987 to the fall of 1988. Collected samples were studied with a binocular microscope and thin sections were studied with a petrographic microscope. Mineral identifications were confirmed by X-ray diffraction (XRD), using a Siemens D-500 semi-automated diffractor. Specific gravity determinations were performed by weighing samples in air and in water, using a triple-beam balance.

OBSERVATIONS AND DISCUSSION

The St. Peter Sandstone at Buffalo Rock is a very pure quartz arenite. The grains, of medium size, are well-sorted and well-rounded. Crystal overgrowths and pressure solution surfaces are sufficiently prevalent to close much of the original porosity, but not so common as to totally indurate the rock. Willman et al. (1975) describe the rock as locally cemented with silica, but generally lacking in calcite cement. Odum et al. (1962) comment that in the subsurface the St. Peter is tightly cemented by calcite and suggest that the absence of calcite cement near the surface is due to solution and removal by near-surface groundwater. Calcite cement is scattered throughout the thin-sections of rock I sampled from the stripped surface. Four pieces of sandstone were treated with dilute HCl to determine calcite content. The results indicated a range of 8.76 to 10.38 weight percent calcite, with a mean of 9.71 percent (equal to a mean of 9.5 volume percent).

Pyrite nodules occur in the top of the St. Peter Sandstone immediately below the unconformity with the overlying Pennsylvanian rocks. They are most commonly found where the rocks above the St. Peter have been removed and the surface of the St. Peter is exposed. The nodules can be found at several such places along the north side of Buffalo Rock. A contour map of the most easily accessible site, located a short distance west of the western-most parking area at the State Park, is shown in Figure 1. The arrow on the map points to an exposure of the

unconformity, where the Colchester (No. 2) Coal overlies the St. Peter. The stippled area marks the stripped surface of the St. Peter where the pyrite nodules occur. The embayment in the contours is an abandoned quarry that served as a source of moulding sand. Additional sites are located (1) in a gully about 0.5km (0.3 miles) west of the above location and (2) above an abandoned quarry at the western end of Buffalo Rock.

The pyrite occurs in the upper one meter (3 feet) of the sandstone as nodules ranging in size from several centimeters to one meter in the longest dimension. Some of the nodules are elliptical, spheroidal or discoidal, but most are very irregular in shape. Many of the individual nodules are surrounded by a white, bleached rim, which itself is surrounded by a dark rusty-brown limonite staining (Fig. 2), described in more detail later.

There are two main stratigraphic and structural controls that influence the location of the pyrite in the sandstone: (1) bedding and cross-bedding planes (Fig. 3), and (2) irregular vertical joints and fractures (Fig. 4). Many of the fractures form a crude polygonal pattern on the surface. In cliff faces the fractures can be seen to pinch out at depths estimated at approximately six to ten meters (20-33 feet). Sandstone filling the cracks is slightly more iron-stained than the rest of the sandstone. There is a suggestion that the pre-Colchester fractures were infilled with sand, which recemented during a period of exposure of the St. Peter.

The pyrite that comprises the nodules is in the form of localized cement in the sandstone. In most nodules the pyrite is massive and encloses quartz grains. Near the margins of the nodules, and in places where the pyrite is not so massive, some cubic crystals containing quartz grains are present (upper-left section of Figure 5a). Crystals of pyrite as large as 2mm were found.

Observations with both binocular and petrographic microscopes reveal a major contrast in sandstone texture between the nodules and the host rock. Within the host rock the quartz grains are vitreous and angular, with crystal overgrowths and calcite cement that lock the grains (Fig. 5a). There is little remaining porosity. Within the nodules the pyrite surrounds rounded grains having a dull luster and pitted surface (Fig. 5b). The change in texture is abrupt and occurs at the margins of the nodules. In some nodules that contain streaks of non-pyritized sandstone, the quartz grains have overgrowths where the pyrite is lacking. However, there are parts of the sandstone in which only minor amounts of pyrite are present, forming a thin layer on the outside of quartz overgrowths. This last observation indicates that the timing of pyritization was post-overgrowth.

The textural comparison described above strongly suggests that the pyrite was deposited by replacement, particularly by selective replacement of pre-existing calcite cement and quartz overgrowths, as well as by the filling of the small amount of remaining pore space. To a lesser extent it appears that parts of some of the original quartz grains may have been replaced also. Additional evidence of replacement is revealed in thin-section. This consists of: (1) pyrite truncating both calcite cement and cement produced by quartz overgrowths; and (2) minute embayments of pyrite into quartz grains; and (3) the fact that pyrite occupies more space than is available as porosity in the other parts of the rock.

In support of point 3 above, a specific gravity determination of a particularly well-cemented nodule yielded a value of 3.25. This indicates that 25.3 volume percent of the sample is pyrite, assuming the remainder to be quartz. It is apparent

in the thin sections that, where no pyrite is present, the rock porosity is considerably less than 25%. In addition, this amount of pyrite is much more than the 9.5% calcite present in the sandstone, indicating that some quartz must have been replaced, as well as the calcite.

Many of the pyrite nodules are surrounded by a rim or halo of white material adjacent to the pyrite. These rims are usually on the order of 3-10mm wide and they are often differentially weathered away. They are absent a few centimeters inside the rock, away from an exposed surface. The material that comprises the white rims surrounding the nodules is a soft cement that was identified by XRD as gypsum. The way gypsum surrounds rounded quartz grains is similar to the occurrence of the pyrite. The sandstone immediately surrounding the gypsum rims is stained dark rusty-brown with limonite, becoming lighter away from the nodules (Fig. 2, 3 and 4). The penetration of the limonite stain may be as little as 1mm into the rock. The stained sandstone has quartz overgrowths, with the boundary between the gypsum and limonite coinciding with the textural change. Thus, the gypsum most likely marks the original extent of the pyrite nodules. Both the gypsum and the limonite are the result of oxidation of the pyrite and can be explained by the equation:

$$190_2 + 8Ca^{+2} + 18H_2O + 4FeS_2 = 8\ (CaSO_4 \cdot 2H_2O) + 4FeO \cdot OH.$$

The source of the calcium could be from dissolved ions in groundwater or from the calcite cement within the rock.

A possible explanation why pyrite nodules are located in the top of the St. Peter can be found by looking at the local stratigraphy and structure, a schematic diagram of which is provided in Figure 6. The main structural feature of the area is the LaSalle Anticline, an asymmetric fold trending S20°E, with the west limb having the steeper dip. Folding was initiated during Ordovician time and continued episodically into post-Pennsylvanian time, with the axis continually shifting eastward (Cady, 1920; Clegg, 1965; and Nelson et al., 1988). During the Middle Ordovician the axis was near the city of LaSalle and during the deposition of the Colchester Coal it was at Buffalo Rock. A considerable amount of folding, uplift and erosion preceded deposition of Pennsylvanian sediments, producing a major unconformity.

The stratigraphic section in the central part of Buffalo Rock consists of the Ordovician St. Peter Sandstone overlain unconformably by the Colchester (No. 2) Coal at the base of the Pennsylvanian Carbondale Formation. Approximately 305 meters (1,000 feet) of section is missing at the unconformity here. The coal is 51cm (20 inches) thick and is overlain by the Francis Creek Shale. The coal thickens to the east and to the west, as this marks the axis of the LaSalle Anticline for that unit (Willman and Payne, 1942; Nelson et al., 1988). Also to the east and to the west, the Pennsylvanian rocks overlie strata younger than the St. Peter and the basal unit of the Pennsylvanian rocks is stratigraphically lower than the Colchester Coal (Fig. 6). According to Willman and Payne (1942) and Odum et al. (1962) underclay of the coal overlies the St. Peter at the west end of Buffalo Rock and to the east and south of Buffalo Rock. However, the Colchester Coal directly overlies the St. Peter Sandstone at the abandoned quarry at the west end of Buffalo Rock. No underclay was observed there.

Outcrops west of Buffalo Rock, up to the west end of Starved Rock State Park, were field-checked in order to observe exposed surfaces of the St. Peter for pyrite

and to note the overlying units. In all cases the St. Peter was overlain by either the underclay of the Colchester Coal or by glacial drift. In no case was pyrite found where units other than the coal directly overlie the St. Peter. In other words, the presence of coal overlying the St. Peter appears to be intimately tied to the occurrence of pyrite.

The relationship between pyrite formation and reducing conditions has been well established in laboratory studies (Krumbein and Garrels, 1952) and such relationships noted petrographically and in the field are too numerous to cite individually. A discussion of some of these is given in Kirchner (1985). Pyrite formation most likely resulted from a reaction of iron ions in groundwater with hydrogen sulfide gas associated with decaying vegetation in the swamp or with the later coalification processes. At Buffalo Rock reducing conditions existed in the top of the St. Peter Sandstone where it served as the substrate for the Colchester Coal. Where the coal overlies the St. Peter, approximately the upper one half meter (1.5 feet) of the sandstone is medium to dark gray, colored by an abundance of organic matter. Plant roots and stagnant water extended down into it. In one place a large cast of a root was found in the sandstone. The anoxic conditions present here were certainly suitable for pyrite formation. This organic-rich zone is absent where the sandstone is overlain by units other than the coal.

It is also possible that the pyrite did not form during the period of the swamp's existence, but instead formed later during the coalification process. With compaction, gases and anoxic waters would have been squeezed out of the organic layer and down into the St. Peter. A thick shale above the coal would have restricted an upward flow. Such fluids not only could have been the agents for precipitation of pyrite in the sandstone, but most likely being acidic, could have easily facilitated the replacement of calcite cement by the pyrite.

Some consideration must be given to the possibility that the pyrite formed by groundwater interaction with the coal at some time later than the compaction of the coal, perhaps as late as the Pleistocene. In such a case, downward percolating water would have had to penetrate the Francis Creek Shale and the coal in order to reach the St. Peter Sandstone. Given the general impermeability of clay-based rocks, this seems the least likely explanation.

INTERPRETATIONS AND CONCLUSIONS

The pyrite occurs as concentrations of cement in the St. Peter Sandstone, occupying some primary intergranular porosity and, to a larger extent, replacing earlier quartz and calcite cement. The pyrite deposition was structurally controlled by permeability channels along bedding and cross-bedding planes and along joints.

The presence of the coal directly over the St. Peter was a critical association in the formation of the pyrite. To my knowledge, pyrite is not present in the St. Peter where overlain by units other than the coal. Either the swamp environment that existed during deposition of the coal or the later coalification processes provided the reducing conditions and hydrogen sulfide needed to form the pyrite. In the first case the pyrite would have originated by precipitation from anoxic groundwater that extended beneath the coal swamp into the St. Peter substrate. The organic-rich top of the St. Peter indicates that this condition existed. In the second case anoxic water would have been squeezed into the St. Peter during compaction of the

organic matter as a part of the coalification processes. It is not possible to tell which method resulted in the pyrite precipitation or if both were involved in the process.

Many of the pyrite nodules exposed on the surface are surrounded by white rims of gypsum cement, with outer zones of dark limonite. They are the result of pyrite oxidation, possibly since exposure due to stripping. These are not present for a depth of more than a few centimeters below the immediate surface, and in some cases not for more than a few millimeters.

ACKNOWLEDGMENTS

I wish to thank Robert S. Nelson and Thomas K. Searight for reviewing the initial manuscript and for their suggestions toward improvement of it. Will McCracken and an anonymous reviewer made constructive comments that led to the final version.

LITERATURE CITED

Cady, G.H., 1919. Geology and mineral resources of the Hennepin and LaSalle Quadrangles; Illinois State Geological Survey Bulletin 37; 136p.

Cady, G.H., 1920. The structure of the LaSalle Anticline; in Illinois State Geological Survey Bulletin 36, 85-179.

Clegg, K.E., 1965. The LaSalle Anticlinal Belt and adjacent structures in east-central Illinois; Transactions of the Illinois State Academy of Science, V. 58, 82-94.

Kirchner, J.G., 1985. Detrital and authigenic pyrite in Illinoian lacustrine silt, central Illinois; Journal of Sedimentary Petrology, V. 55, 869-873.

Krumbein, W.C. and R.M. Garrels, 1952. Origin and classification of chemical sediments in therms of pH and oxidation-reduction potentials; Journal of Geology, V. 60, 1-33.

Nelson, R.S., J.G. Kirchner and T.K. Searight, 1988. Guidebook for the 52nd Annual Tri-State Geological Field Conference: The LaSalle Anticline and its influence on Pennsylvanian sedimentation in the LaSalle-Peru area; Illinois State University; Normal; 49p.

Odum, E., G.M. Wilson and G. Dow, 1962. Starved Rock Area: Illinois State Geological Survey Guide Leaflet 1962-A; 33p.

Reinertsen, D.L. and M.M. Killey, 1971. LaSalle Area: Illinois State Geological Survey Guide Leaflet 1971-D; 43p.

Templeton, J.S. and H.B. Willman, 1963. Champlainian Series (Middle Ordovician) in Illinois: Illinois State Geological Survey Bulletin 89; 260p.

Willman, H.B., E. Atherton, T.C. Buschbach, C. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback and J.A. Simon, 1975. Handbook of Illinois Stratigraphy: Illinois State Geological Survey Bulletin 95; 261p.

Willman, H.B. and J.N. Payne, 1942. Geology and Mineral Resources of the Marseilles, Ottawa and Streator Quadrangles: Illinois State Geological Survey Bulletin 66; 388p.

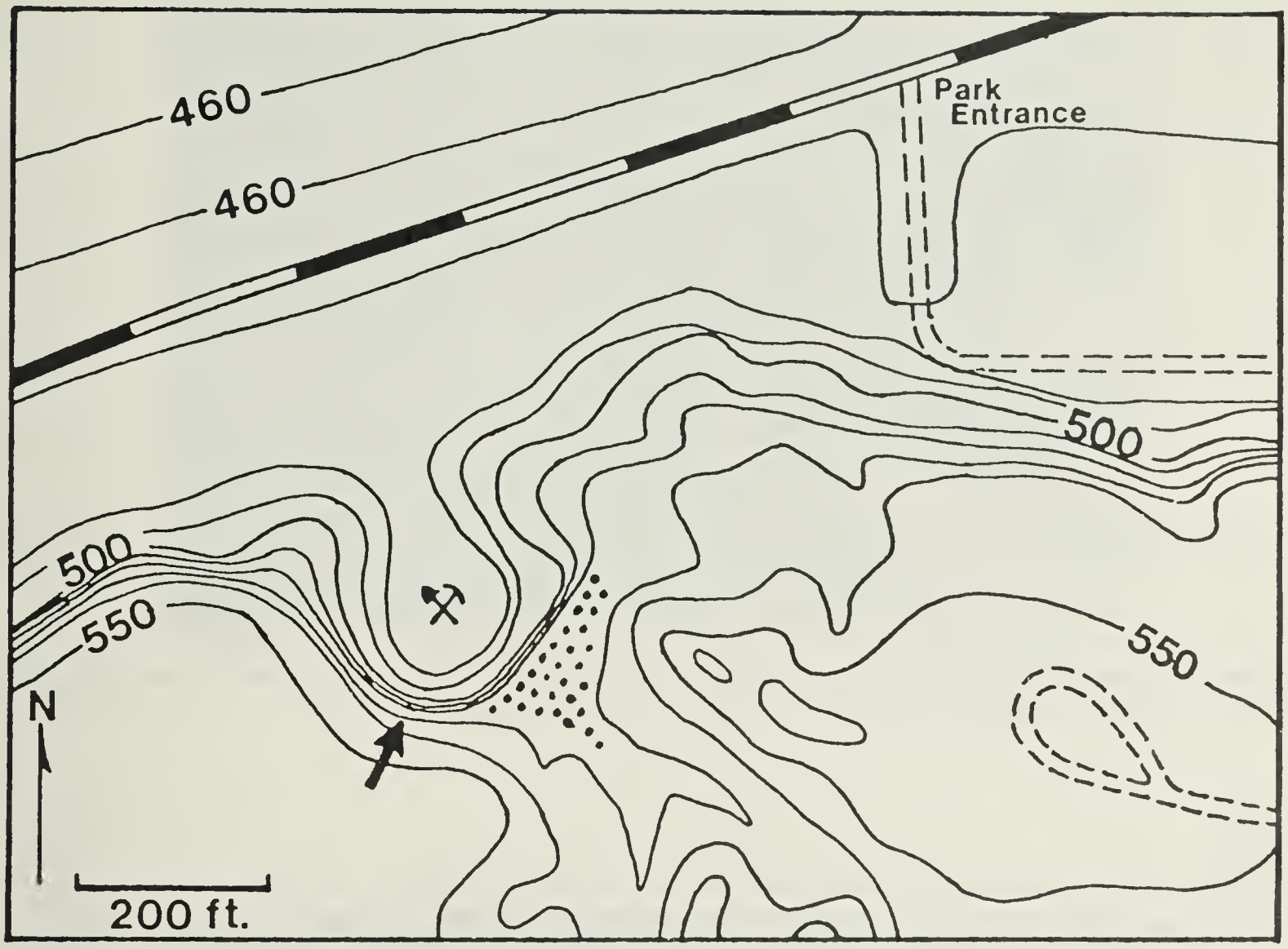

Figure 1. Topographic map of an outcrop of pyrite-bearing St. Peter Sandstone at Buffalo Rock State Park. Original base map is Starved Rock Quadrangle, 1:24,000.

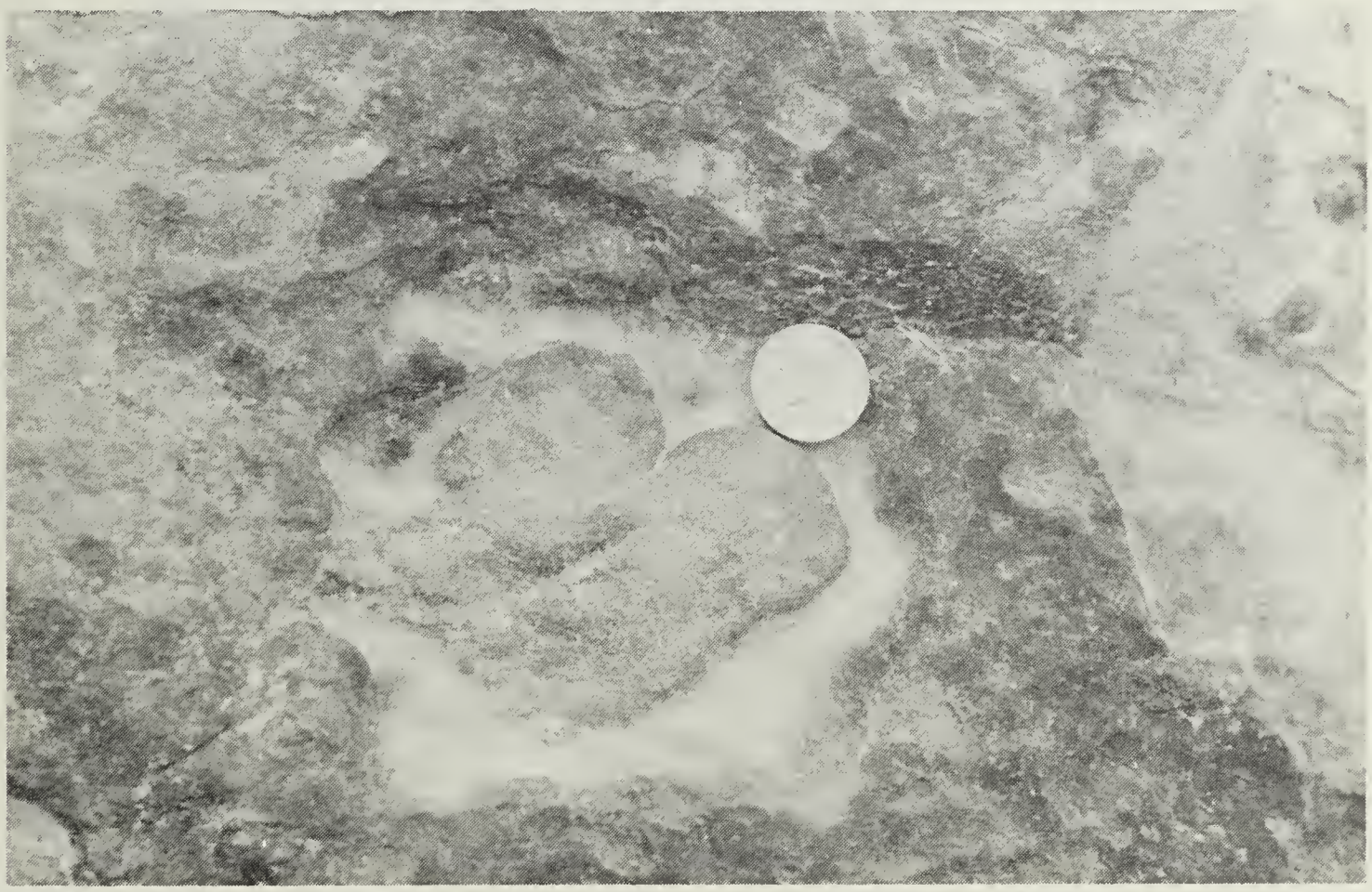

Figure 2. Close-up view of a pyrite nodule surrounded by a white rim of gypsum-cemented sandstone and by limonite staining. Coin is 21mm (0.8 inches) in diameter.

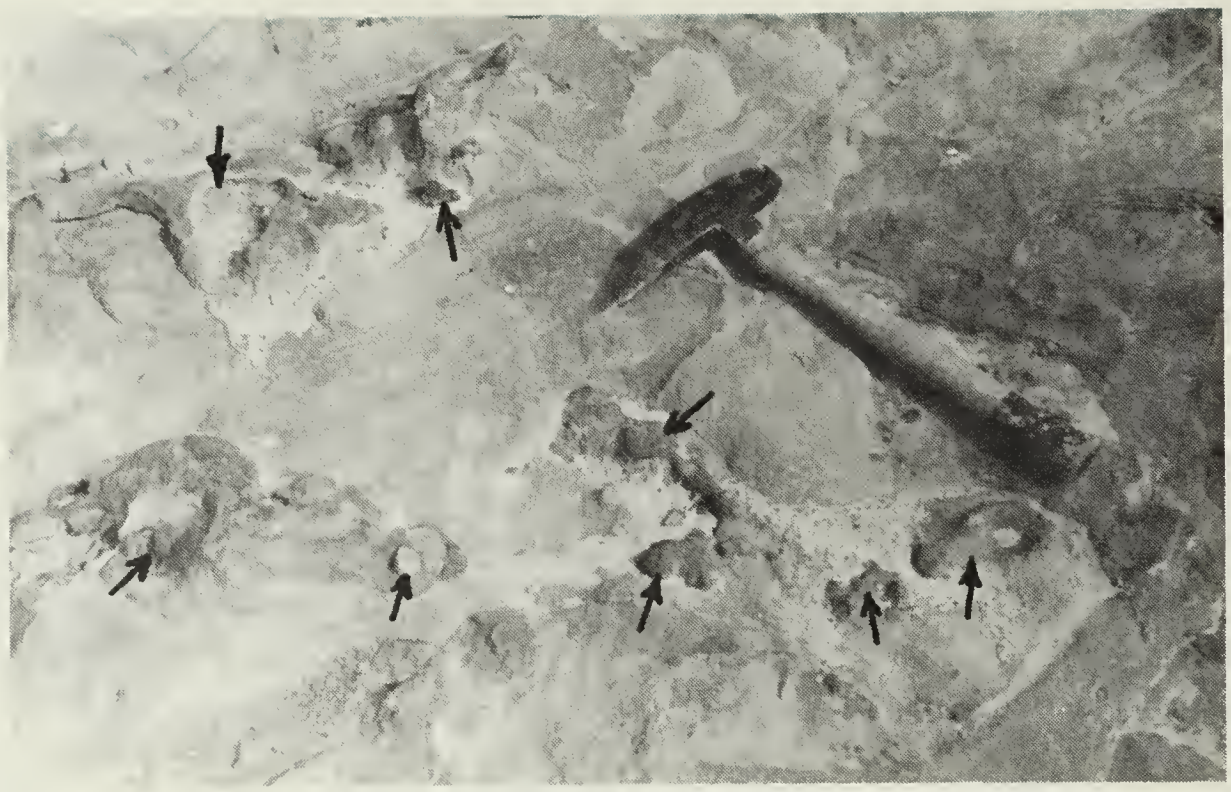

Figure 3. Pyrite nodules (arrows) concentrated on a bedding-plane surface near the top of the St. Peter Sandstone. Hammer is 35cm (14 inches) long.

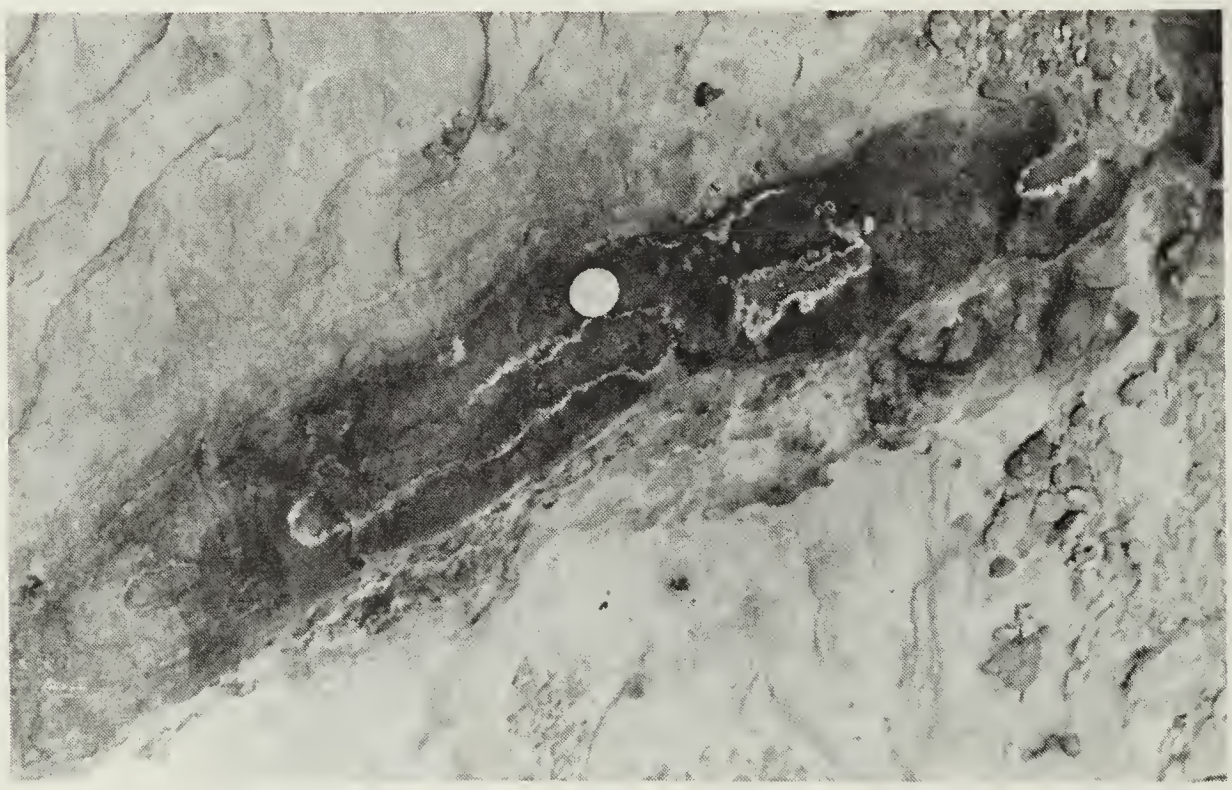

Figure 4. Bedding-plane view of a vertical joint along which elongate pyrite nodules occur. Nodules are surrounded by thin white rims and a band of dark brown limonite stain. Coin is 21mm (0.8 inches) in diameter.

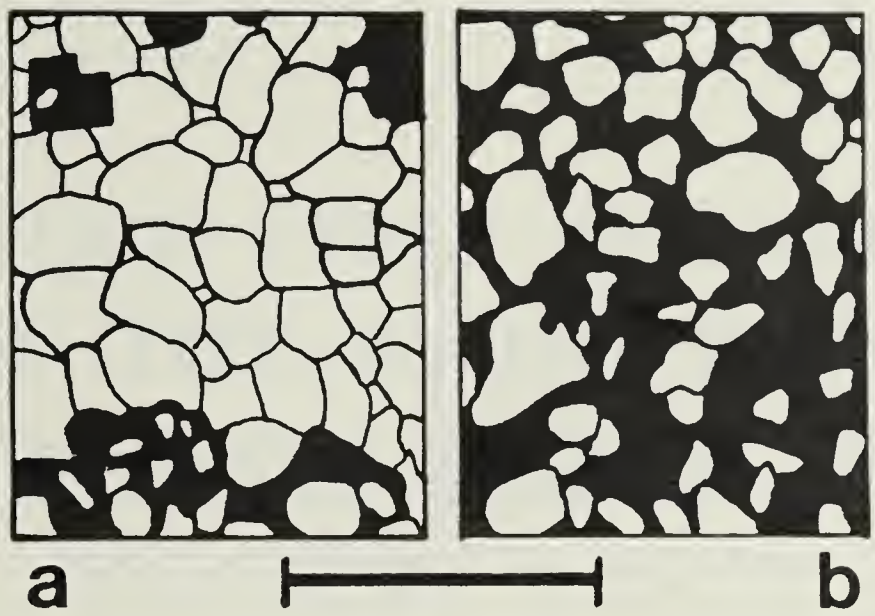

Figure 5. Camera-lucida drawings comparing textures of thin sections of St. Peter Sandstone. Black areas are pyrite, white are quartz grains. Scale bar is 1mm.
a. View of sandstone with little pyrite. Note the interlocking angular grains.
b. Section of a pyrite nodule. Note the lack of overgrowths on the grains.

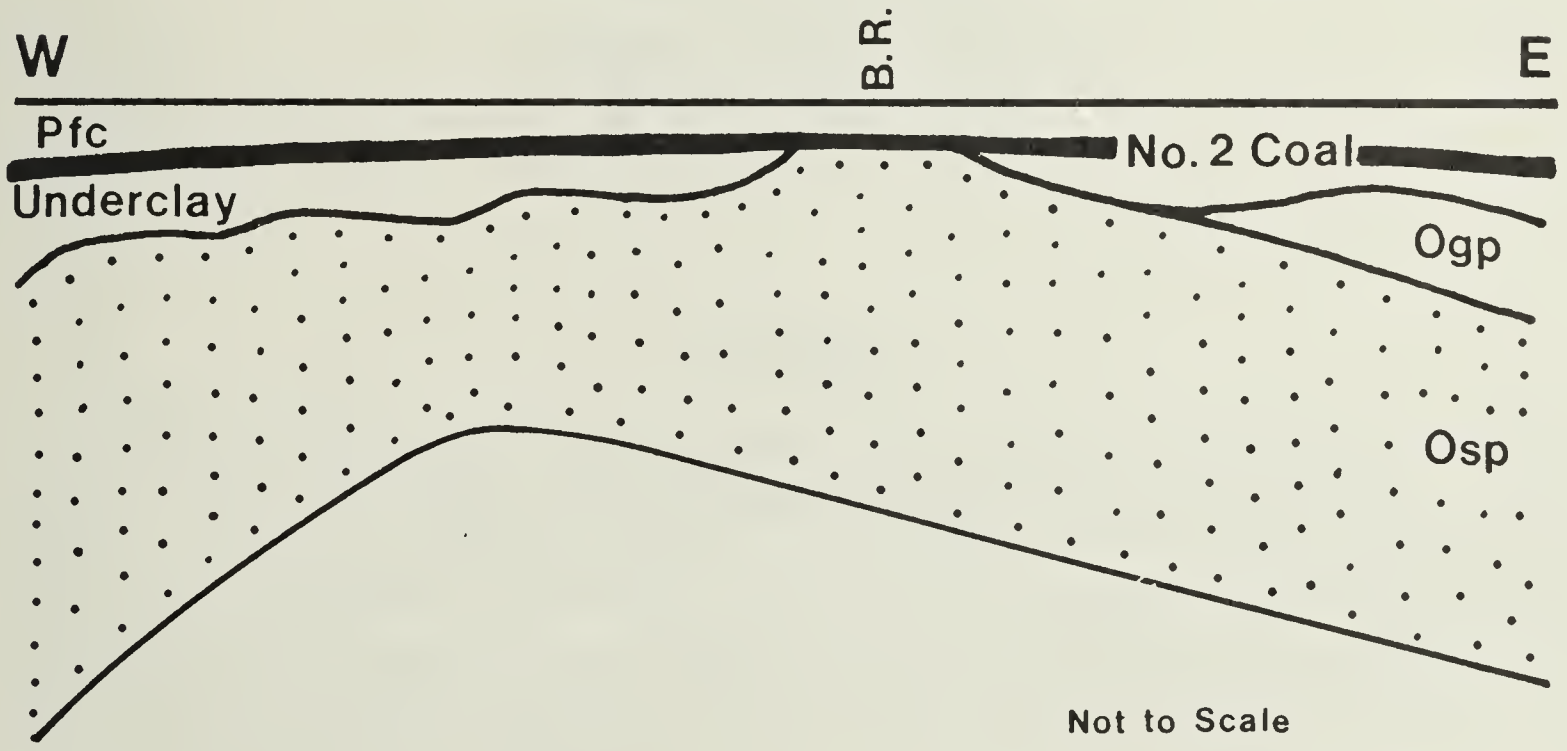

Figure 6. Schematic structural cross-section through the Buffalo Rock (B.R.) area. Osp: St. Peter Sandstone; Ogp: Galena-Platteville Group; Pfc: Francis Creek Shale.

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THE FIRST RECORD OF THE WHITE PERCH (MORONE AMERICANA) IN ILLINOIS WATERS OF LAKE MICHIGAN

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ABSTRACT

This is the first report of a white perch (*Morone americana*) captured in Illinois waters of Lake Michigan. The fish was captured by electro-shocking in Belmont Harbor in Chicago, Illinois on September 14, 1988. The total length of the fish was 16 cm and weighed 59 g. This fish species occurs in Green Bay, Wisconsin (Richard Hess, personal communication, Illinois Department of Conservation), but this is the first report of this fish occurring in Illinois waters of Lake Michigan. Smith (1979) did not report the fish in Illinois.

The white perch is predominantly brackish-water species but also occurs in some freshwater lakes and ponds along the east coast of the United States (Mansueti, 1961). It appeared in substantial numbers in Lake Ontario in the early 1960's, and Scott and Christie (1963) suggested that white perch invaded Lake Ontario by western movement through the Hudson River and the Erie Barge Canal. This report confirms that the fish in continuing to increase its range and is present in Illinois waters of Lake Michigan.

ACKNOWLEDGMENTS

We thank Dr. Lawrence Page and Dr. C. Leavett Smith for confirming the identification of the specimen. The specimen (catalogued as INHS 64428) now resides in the fish collection at the Illinois Natural History Survey in Champaign,

Illinois. The collection of this specimen was part of a project funded by the Illinois Department of Conservation, F-93-R.

LITERATURE CITED

Manseuti, R. 1961. Movements, reproduction and mortality of the white perch, Roccus americanus, in the Patuxent Estuary, Maryland. Chesapeake Science 2: 142-205.

Scott and Christie. 1963. The invasion of the lower Great Lakes by the white perch, Roccus americanus (Gmelin). J. Fish. Res. Bd. Canada 20: 1189-1195.

Smith, P.W. 1979. The Fishes of Illinois. University of Illinois Press. Champaign, Illinois.

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REPRODUCTIVE BIOLOGY OF THE INLAND SILVERSIDE, MENIDIA BERYLLINA IN SOUTHERN ILLINOIS

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ABSTRACT

The potential use of the inland silverside, *Menidia beryllina*, as forage for sportfishes in southern Illinois reservoirs is largely dependent on the ability to produce abundant offspring north of its native range. We investigated the reproductive biology of the inland silverside and found that its breeding season in southern Illinois begins in late April or early May. When inland silverside density is high the breeding season ends in July, however, when density is relatively low the breeding season can continue into October. Two spawning peaks occur if the breeding season continues into October: the first in May or June and the second, much smaller peak, in September. First generation inland silverside are capable of reproducing and can account for extension of the breeding season into October. The reproductive potential of the inland silverside in southern Illinois is greater than that of the brook silverside, *Labidesthes sicculus*; they produced approximately six times more larvae than the brook silverside in predator-free ponds. Inland silverside can build up a large population within 1 year of stocking and many prove efficacious as forage for sportfishes in some southern Illinois reservoirs.

INTRODUCTION

The inland silverside is utilized as forage by sportfishes in waters where it is abundant (Echelle and Mense 1966; Moyle and Holzhauser 1978; Moser 1968). It

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lives in coastal and freshwater habitats from Maine to southwestern Gulf of Mexico and its interior range extends as far north as the confluence of the Mississippi and Ohio rivers (Gilbert and Lee 1980). One specimen was taken in April 1978 from the Mississippi River near Grand Tower, Illinois. No other specimen has been found in Illinois (Burr et al. 1988). The interior range does not normally extend beyond the southern United States because the inland silverside is unable to tolerate relatively cold temperature (Hubbs et al. 1971; Stoeckel and Heidinger 1988). Its usefulness as forage north of its native range is largely dependent on the ability to build up large populations quickly following winter die-offs. This study addresses some of the factors that influence the inland silverside's reproductive capacity in southern Illinois.

The inland silverside is fecund as exemplified by the build up of a very large population within 1 year after it was stocked into a California reservoir (Cook and Moore 1970). Females spawn several times during the breeding season (Mense 1967), and may be capable of producing clutches of eggs daily during the breeding season (Hubbs 1976). Inasmuch as the inland silverside is a multiple spawner, seasonal fecundity is a function of mean number of eggs laid per day and length of spawning season.

Reports on duration of the spawning season vary. Mense (1967) and Hubbs and Bailey (1977) report that spawning in Lake Texoma, Oklahoma, typically occurs from late March or early April to mid-July. However, Taber (1969) collected recently hatched larvae as late as September in Lake Texoma. Hildebrand (1923), Cook and Moore (1970), and Fisher (1973) found evidence, in the form of small fry, that the inland silverside spawns as late as September in North Carolina and north central California.

In a lab study, Hubbs and Bailey (1977) correlated temperature $\geq 31°C$ with termination of spawning of the inland silverside. Field evidence that spawning of inland silverside in Lake Texoma, Oklahoma, ceases at high temperature includes a low frequency of ripe adults during an extremely warm June, followed by a high frequency of ripe adults in mid-July after temperatures had moderated (Hubbs and Bryan 1973). Hubbs and Bailey (1977) also collected ripe adults 2 weeks later than normal during an unusually cool summer. Inasmuch as cessation of spawning is correlated with high temperature, we speculated that summer temperatures cooler than those of the inland silverside's native range may increase the length of the inland silverside's spawning season.

Young-of-the-year reproduction can contribute significantly to the reproductive capacity of forage fishes. For example, reproduction by young-of-the-year threadfin shad, *Dorosoma petenense*, can lead to the build up of extremely large populations within several months when adults are stocked in the spring at low density (Heidinger and Imboden 1974). Cook and Moore (1970). Hubbs and Dean (1979) and Hubbs (1982) have found what they considered to be ripe young-of-the-year inland silverside, but recruitment from first generation inland silverside has not been documented in the literature.

This study was undertaken to evaluate the reproductive biology of the inland silverside in southern Illinois by estimating the number of larvae produced throughout the breeding season, determining the duration of the spawning season, and assessing whether young-of-the-year can reproduce. In addition, we compared

the length of the spawning season of the inland silverside with that of the commonly occurring brook silverside, *Labidesthes sicculus*.

MATERIALS AND METHODS

Study Sites

Fish culture ponds free of other fish and two privately owned ponds with established fish communities were used in this study. The fish culture ponds range in size from 0.04 to 0.06 hectars. The mean depth of these ponds is 0.8 m, maximum depth is 1.8 m and the water supply flows by gravity from a 55-hectare reservoir located above the ponds. Knapp's Pond is a 1.2-hectare, privately owned pond constructed for recreational use. It has a maximum depth of 3.5 m. Vegetation in the pond covers only about 5% of the surface in mid-summer. The fish community is typified by many bluegill, *Lepomis macrochirus*, $<$ 125 mm in total length (TL), and moderate numbers of largemouth bass, *Micropterus salmoides*, and channel catfish, *Ictalurus punctatus*. Other taxa occasionally observed in the pond include the warmouth, *Lepomis gulosus*, green sunfish, *Lepomis cyanellus*, golden shiner, *Notemigonus crysoleucas*, blackstriped topminnow, *Fundulus notatus*, common carp, *Cyprinus carpio*, yellow bullhead, *Ictalurus natalis*, and *Lepomis* hybrids. Petersen's Pond is also a privately owned pond constructed for recreational use. It is 3.0-hectares in area with a maximum depth of 3.0 m. This pond is typified by a substantial number of bluegill $\geq$ 150 mm TL and largemouth bass $<$ 300 mm TL. Other taxa occasionally observed were the lake chubsucker, *Erimizon sucetta*, and *Lepomis* hybrids. Vegetation consists of several stands of cattails, *Typha* sp., and dense beds of other macrophytes, primarily *Ceratophyllum* spp., that normally cover greater than 60% of the surface in mid-summer.

All bodies of water used in this study are located north of the native range of the inland silverside (37° 00′ latitude north). The sample sites are located in southern Illinois between 37° 30′ and 38° 30′ latitude north.

Procedure

Inland silversides overwintered indoors were stocked into all experimental ponds in the spring of 1980. The fish culture ponds and Petersen's Pond were restocked in 1981. Brook silversides were also stocked into a fish culture pond in 1981. In 1981, biweekly meter net samples were taken to determine the duration and intensity of spawning of the silversides with respect to time and temperature. Triplicate meter net (1.0 m diameter, 0.9 mm bar mesh, 2.5 m long cone) samples were taken on each sample date in Knapp's Pond and Petersen's Pond. We towed the meter net behind a small boat and outboard at a mean velocity of 0.85 m/sec.

To avoid contact with the substratum in the shallow fish culture ponds, the meter net was modified by placing floats opposite each other so that half of the net was above the water's surface. The net was pulled the length of the pond by hand at a rate of approximately 0.9 to 1.0 m/sec. A flowmeter (General Oceanics, Inc.® digital model 2030) was used for all samples to determine the distance over which the net traveled. Because the fish culture ponds are small, only one meter net sample was taken in each pond on each sample date to prevent oversampling. All meter net samples were collected at night since other researchers have found the distribution of larvae of other species to be more uniform at night (Netsch et al. 1971; Tuberville

1979). In addition, Taber (1969) reported higher catches of larval inland silverside at night.

Initial meter net samples did not contain larval inland silverside, but 2 weeks later inland silverside as long as 15 mm TL were captured. Consequently, inland silverside $\leq$ 15 mm TL were considered to be indicative of recent spawning, and the number of larvae $\leq$ 15 mm TL was considered a minimum estimate of larvae produced during each 2 week period.

To determine if the open-water meter net samples taken at night were unbiased indicators of larval inland silverside abundance, stratified samples were taken on 7 July 1981 in Knapp's Pond. The samples were stratified according to time and depth. Paired samples were taken approximately every 3.5 hours from dawn until after dark; six offshore and six inshore samples were taken. Offshore samples were taken with a meter net towed behind a small boat and outboard similar to the routine samples, and inshore samples were taken with a meter net modified in the same manner as that used in sampling the fish culture ponds. Inshore samples were taken as near to shore as was practical. We also took a series of shoreline seine samples on 7 July to determine relative abundance of the 1980 size class of inland silverside.

Largemouth bass populations of the two private ponds were analyzed to determine if substantial differences between structures of the predator populations existed. Mark and recapture estimates of density were made using the Chapman modification of the Schnabel method (Ricker 1975). Fish were captured by electrofishing and marked with fin clips. Mean weight of a representative sample of fish was multiplied by estimated number to approximate the weight of largemouth bass in each pond. Number and weight values were standardized to number and kg/hectare, respectively.

Ability of young-of-the-year to reproduce was determined by stocking a known number of inland silverside fry in June into a fish culture pond. This experiment consisted of two trials. In 1980, 200 fry were stocked, and in 1981, 400 fry were stocked. The stocking procedure consisted of capturing inland silverside fry with a bucket, counting the fry and releasing them into a pond which did not contain inland silverside. The pond was drained in October and the number and length-frequency distribution of the inland silverside recovered were determined. If the number of inland silverside recovered in the fall was greater than the number stocked in the spring, reproduction by young-of-the-year was considered to have occurred.

RESULTS

Inland silverside overwintered indoors as well as outdoors in ponds reproduced in the spring and summer of 1980 and 1981. In 1980, inland silverside reproduction was confirmed in the fish culture ponds and in Knapp's Pond when numerous young-of-the-year were captured in the summer and fall. Larvae $\leq$ 15 mm TL were collected from May through October 1981 in Knapp's Pond, and from April through July 1981 in fish culture ponds. Density of inland silverside larvae collected was greatest in mid-May in Knapp's Pond (63/100 m^3, Figure 1) and in mid-June in the fish culture ponds (3 pond mean of 3,994/100 m^3, Figure 2). No

inland silverside was collected from Petersen's Pond in either 1980 or 1981.

Brook silverside larvae ≤ 15 mm TL were collected from mid-June to mid-July 1981 in a fish culture pond (Figure 2). The total number of brook silverside larvae collected over the 1981 sampling period (1,505/100 m^3) was approximately six times less than that of inland silverside larvae (9,116/100 m^3) even though the mean density of adults stocked was approximately six times greater in the brook silverside pond (10,000/hectare vs. 1,600/hectare).

In the fish culture ponds, the spawning season of the inland silverside lasted approximately 3 months longer than that of the brook silverside. The brook silverside began spawning approximately 2 months later and stopped spawning approximately 1 month earlier than the inland silverside (Figure 2). A comparison of duration of spawning season between inland silversides in the fish culture ponds (Figure 2) and those in Knapp's Pond (Figure 1) shows that the spawning season in Knapp's Pond, although reduced in intensity, continued for an additional 3 months, into September.

Mean densities of paired samples of inland silverside larvae collected during the diel sampling trial on 7 July were approximately equal for all daytime samples (inshore = 13, 25, 13 and 38/100 m^3; offshore = 0, 0, 2 and 0/100 m^3). Dusk and night samples were also similar (inshore = 204 and 217/100 m^3; offshore = 30 and 11/100 m^3). The ratio of larvae captured during the day versus larvae captured at dusk and night was 1:10, while the ratio of larvae captured offshore in open water versus larvae captured inshore was 1:12.

An analysis of the largemouth bass population structures indicated that while density of fish in terms of weight was greater in Knapp's Pond with 100 kg/hectare vs. 83 kg/hectare, density in terms of numbers was greater in Petersen's Pond with 565/hectare (95% confidence interval = 369-903) vs. 406/hectare (95% confidence interval = 339-488). Length-frequency distributions emphasize the disparity between structures of the two pond's largemouth bass populations (Figures 3 and 4). The oldest age class of fish captured in Petersen's Pond averaged only 276 mm TL while largemouth bass in Knapp's Pond frequently exceeded 300 mm TL.

Reproduction by young-of-the-year fish was confirmed as number of inland silverside recovered was greater than number of inland silverside stocked in both trials. In the first trial, length-frequency data of fish recovered from the fish culture pond stocked with fry in mid-June 1980 showed a bimodal distribution (Figure 5). The transfer of 400 fry to a fish culture pond in June 1981 also led to reproduction by first generation offspring and we again observed a bimodal length-frequency distribution in the fall (Figure 6). Larvae were not abundant in this pond until 11 September. Based on growth rate and size of larvae at that time, spawning of young-of-the-year occurred in early to mid-August, when temperature was ≤ 31°C.

DISCUSSION

The ability of stocked inland silverside to survive in Knapp's Pond but not in Petersen's Pond is attributed to greater predator pressure in Petersen's Pond. Petersen's Pond is characterized by a crowded, slow-growing largemouth bass population, whereas Knapp's Pond has a relatively balanced population (see Figures 3 and 4). A portion of largemouth bass populations in ponds with crowded

populations may have to be removed to permit establishment of a breeding populations of inland silverside.

Density of inland silverside in Knapp's Pond was considerably less than that in the predator-free fish culture ponds. The overall ratio between Knapp's Pond and the fish culture ponds was 1:52. Some of this difference is undoubtedly related to predation on eggs and larvae in Knapp's Pond, but some may also be attributable to sampling technique. The fish culture ponds are small, uniform and shallow, and estimates of larvae in them were considered to be accurate. However, in Knapp's Pond, differences in density of larvae apparently existed between open water and shoreline areas. Based on the series of samples taken on 7 July, open water samples as well as daytime samples underestimate density of larval inland silverside. Visual avoidance of sampling gear is the most probable reason that daytime catches were ten times lower than dusk and night catches, and we attribute greater success of inshore sampling to a greater density of larval inland silverside near shore. Thus, density estimates for Knapp's Pond are probably very conservative due to exclusive open water sampling during our study. We recommend consideration for the horizontal distribution of inland silverside larvae in future studies.

Duration of the spawning season was longer for all inland silverside populations than for the brook silverside, and duration of the spawning season for inland silverside in Knapp's Pond was notably longer than the duration of those held in fish culture ponds. The difference between duration of the inland silverside's and brook silverside's spawning season can be attributed to different reproduction strategies. Brook silverside females spawn only once (Cahn 1927), whereas inland silverside females are capable of spawning daily for an extended time period (Hubbs 1976). Based on this study, annual fecundity of the inland silverside is notably greater than that of the brook silverside. The longer spawning season for inland silverside in Knapp's Pond, when compared to those in the fish culture ponds, may be a result of slightly cooler temperatures in Knapp's Pond (Figures 1 and 2). Hubbs and Bailey (1977) concluded that repeated exposure to high temperature ($\geq$ 31°C) causes a cessation in spawning.

Results of young-of-the-year reproduction trials show they can reproduce if conditions are favorable. In 1980 second generation offspring were approaching the minimum reproductive sizes of approximately 51 mm (males) and 60 mm (females) in standard length as determined by Hubbs and Dean (1979). This implies that second generation offspring may also spawn under suitable conditions. The number of second generation offspring produced during young-of-the-year reproduction trials should not be interpreted as the maximum reproductive potential of first generation offspring because predators, primarily *Lepomis* spp. adults and their young, were present. Production of larvae in late summer and fall is significant, inasmuch as small forage fish would be present at a time when they typically are unavailable in southern Illinois reservoirs.

Of 540 inland silverside captured from Knapp's Pond in a series of seine samples on 7 July 1981, only one was of the 1980 size class (100 mm TL). All others were $<$ 62 mm TL which is less than the minimum size required for sexual maturity of females (Hubbs and Dean 1979). Thus, the July cessation in spawning of the inland silverside observed in this study and in Lake Texoma, Oklahoma, as noted by Mense (1967), and Hubbs and Bailey (1977), corresponds not only to high temperature but to disappearance of adults (Mense 1967; Taber 1969). Taber (1969)

concluded that the spawning season of the inland silverside in Lake Texoma lasted from April to September in 1966. He also noted a reduction in spawning during August, similar to the trend we observed in Knapp's Pond, and attributed late year spawning to the remnant of the adult population even though he collected no adults in August or September. We attribute the secondary peak in larval abundance in Knapp's Pond to spawning of young-of-the-year (Figure 1). The decline in larval recruitment that occurred between the primary and secondary peaks corresponds to a low number of mature fish (i.e. very few fish of the 1980 size class remained and fish of the 1981 size class were only beginning to reach a sexually mature size). Inland silverside collected in October in Knapp's Pond ranged from 30-105 mm TL, indicating that larger fish of the 1981 year class had reached a sexually mature size. No fish of the 1980 size class were collected in the October sample.

Young-of-the-year did not reproduce in fish culture ponds in which density of inland silversides was high. We attribute lack of young-of-the-year reproduction in these ponds to slow growth and concurrent slow sexual maturation of first generation offspring. Only 29 of 2,961 juvenile inland silverside captured incidental to sampling for larvae in August and September were ≥ 60 mm TL. Of these only 7 were ≥ 70 mm TL. We believe that a density of inland silverside, great enough to restrict growth of individuals, is the primary factor controlling reproduction of young-of-the-year fish. This hypothesis is supported by an aberrant occurrence of many large, gravid first generation offspring in Lake Texoma following an unusually cold winter and substantial die-off of adult inland silverside (Hubbs and Dean 1979).

Based on young-of-the-year reproduction trials and the small secondary peak of larvae produced in Knapp's Pond, young-of-the-year inland silverside do not contribute dramatically to overall annual production of young as do young-of-the-year threadfin shad (Heidinger and Imboden 1974). Nonetheless, because fish of the 1981 size class were very abundant in the October sample for Knapp's Pond, it is apparent that the inland silverside can build up a large population within 1 year in some southern Illinois reservoirs and may prove effective as forage.

SUMMARY

The spawning season of the inland silverside in southern Illinois does not vary appreciably from that observed within its native range. Most spawning occurs before August. The disappearance of adults in July, coupled with the ability of young-of-the-year to spawn later in the year, implies that cessation of spawning in July or reduction in spawning during August is not necessarily controlled by temperature but by a lack of sexually mature fish. Based on our findings concerning young-of-the-year reproduction and size-class structures of samples collected from Knapp's Pond it also appears that a continuation of spawning through August and September is dependent primarily on maturation of age 0+ fish and not on a remnant of the adult population. Reproduction by young-of-the-year is relatively insignificant when compared to early season spawning of overwintering adults. Nonetheless, the inland silverside can build up a large population within 1 year of stocking and may prove efficacious as forage for sportfishes in some southern Illinois reservoirs.

ACKNOWLEDGMENTS

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LITERATURE CITED

Burr, B.M., M.L. Warren, Jr., and K.S. Cummings. 1988. New distributional records of Illinois fishes with additions to the known fauna. Transactions of the Illinois Academy of Science 81: 163-170.

Cahn, A.R. 1927. An ecological study of southern Wisconsin fishes. Illinois Biological Monographs 11, 115 pp.

Cook, S.F. and Moore, L.R. 1970. Mississippi silversides, *Menidia audens* (Atherinidae), established in California, Transactions of the American Fisheries Society 99:70-73.

Echelle, A.A. and Mense, J.B. 1966. Forage value of Mississippi silversides in Lake Texoma. Proceedings of the Oklahoma Academy of Science 47:393-396.

Fisher, F. 1973. Observations on the spawning of the Mississippi silversides, *Menidia audens*, Hay. California Fish and Game 59:315-316.

Gilbert, C.R. and Lee, D.S. 1980. *Menidia beryllina* (Cope), Tidewater silverside. Atlas of North American Freshwater Fishes. D.S. Lee et al., editors, p. 558. North Carolina State Museum of Natural History, Raleigh.

Heidinger, R. and Imboden, F. 1974. Reproductive potential of young-of-the-year threadfin shad (*Dorosoma petenense*) in southern Illinois lakes. Transactions of the Illinois Academy of Science 67:397-401.

Hildebrand, S.F. 1923. Notes on habits and development of eggs and larvae of the silversides *Menidia menidia* and *Menidia beryllina*. U.S. Bureau of Fisheries Bulletin 38:113-120.

Hubbs, C. 1976. The diel reproductive pattern and fecundity of *Menidia audens*. Copeia 2:386-388.

Hubbs, C. 1982. Life history dynamics of *Menidia beryllina* from Lake Texoma. American Midland Naturalist 107:1-12.

Hubbs, C. and Bailey, H.H. 1977. Effects of temperature on the termination of breeding season of *Menidia audens*. Southwestern Naturalist 22:557-562.

Hubbs, C. and Bryan, C. 1973. Effect of parental temperature experience on thermal tolerance of eggs of *Menidia audens*. The Early Life History of Fish. J.H.S. Blaxter, editor, pp. 431-435. Springer-Verlag, New York.

Hubbs, C. and Dean, S.M. 1979. Growth and reproductive responses of *Menidia beryllina* (Atherinidae) inhabiting Lake Texoma. Southwestern Naturalist 24:546-549.

Hubbs, C., Sharp, H.B. and Schneider, J.F. 1971. Developmental rates of *Menidia audens* with notes on salt tolerance. Transactions of American Fisheries Society 100:603-610.

Mense, J.B. 1967. Ecology of the Mississippi silversides, *Menidia audens* Hay, in Lake Texoma. Oklahoma Fisheries Research Laboratory Bulletin 6, 32 pp.

Moser, B.B. 1968. Food habits of white bass in Lake Texoma with special reference to the threadfin shad. M.S. thesis. University of Oklahoma, Norman.

Moyle, P.B. and Holzhauser, N.J. 1978. Effects of the introduction of Mississippi silverside (*Menidia audens*) and Florida largemouth bass (*Micropterus salmoides floridanus*) on the feeding habits of young-of-the-year largemouth bass in Clear Lake, California. Transactions of the American Fisheries Society 107:574-582.

Netsch, N.F., Kersh, G.M., Jr., Houser, A. and Kilambi, R.V. 1971. Distribution of young gizzard shad and threadfin shad in Beaver Reservoir. Reservoir Fisheries and Limnology. G.E. Hall, editor, pp. 95-105. Special Publication Number 8, American Fisheries Society, Washington, D.C.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board Canada Bulletin 191:382 pp.

Stoeckel, J.N. and R.C. Heidinger. 1988. Overwintering of the inland silverside in southern Illinois. North American Journal of Fisheries Management 8:127-131.

Taber, C.A. 1969. The distribution and identification of larval fishes in the Buncombe Creek arm of Lake Texoma with observations on spawning habits and relative abundance. Ph.D. thesis. University of Oklahoma, Norman.

Tuberville, J.D. 1979. Vertical distribution of ichthyoplankton in upper Nickajack Reservoir, Tennessee, with comparisons of three sampling methodologies. Proceedings of the Third Annual Symposium on Larval Fish. R.D. Hoyt, editor, pp. 185-203. Western Kentucky University, Bowling Green.

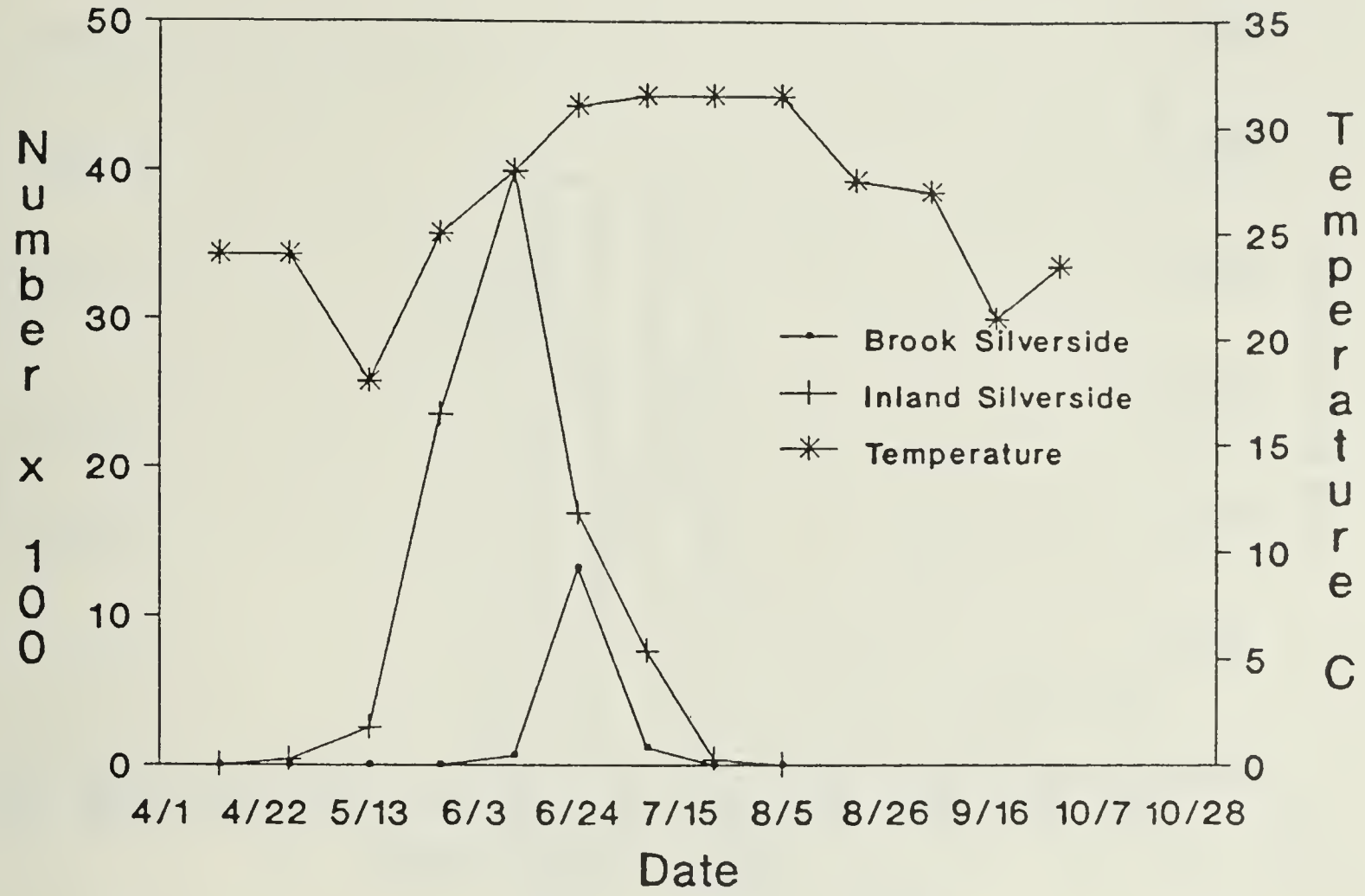

Figure 1. Number of *Menidia* larvae ≤ 15 mm in total length per 100 m^3 captured in Knapp's Pond, 1981.

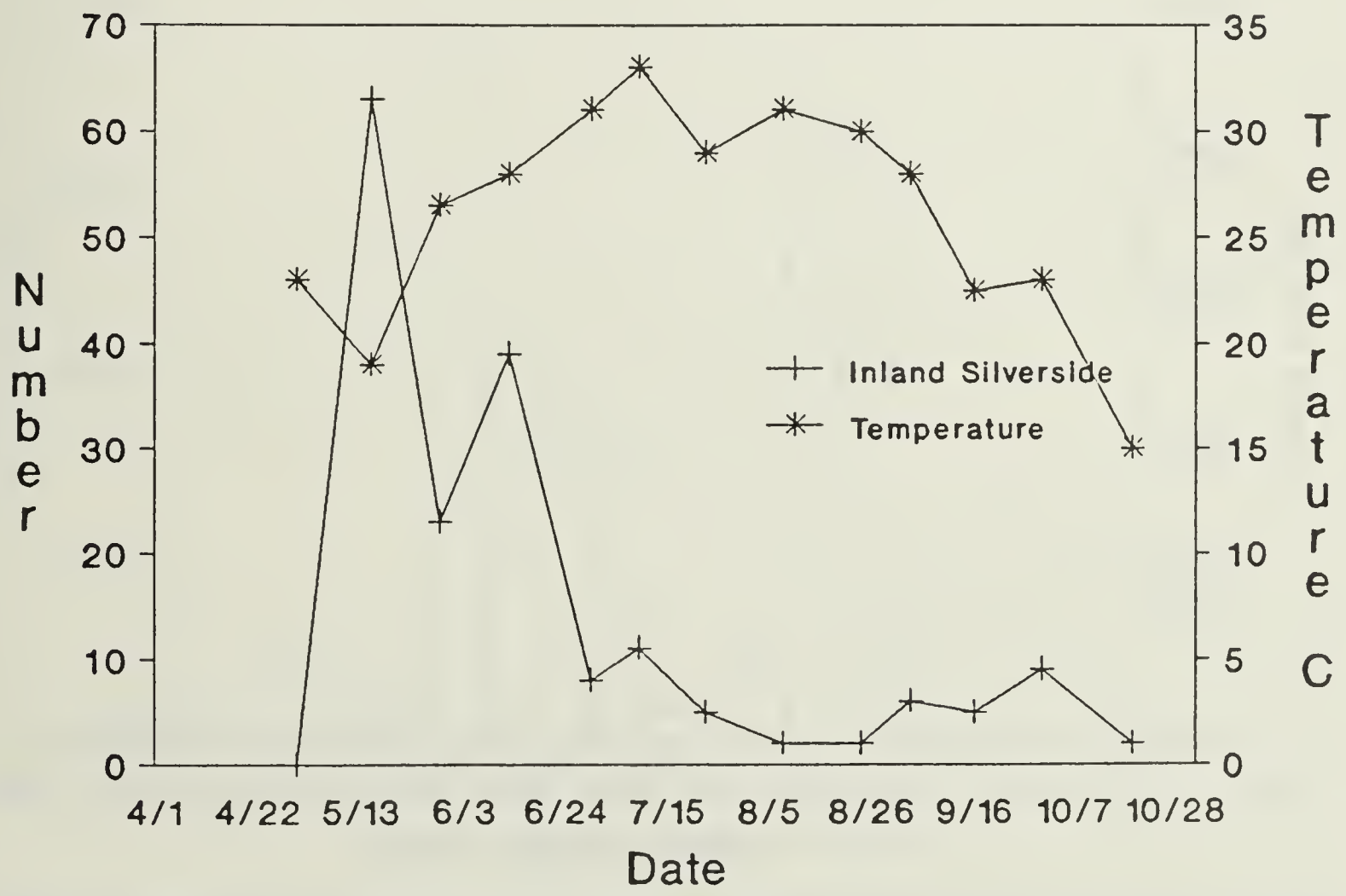

Figure 2. Number of *Menidia* (3 pond mean) and *Labidesthes* (1 pond) larvae ≤ 15 mm in total length per 100 m^3 captured in predator-free fish culture ponds, 1981.

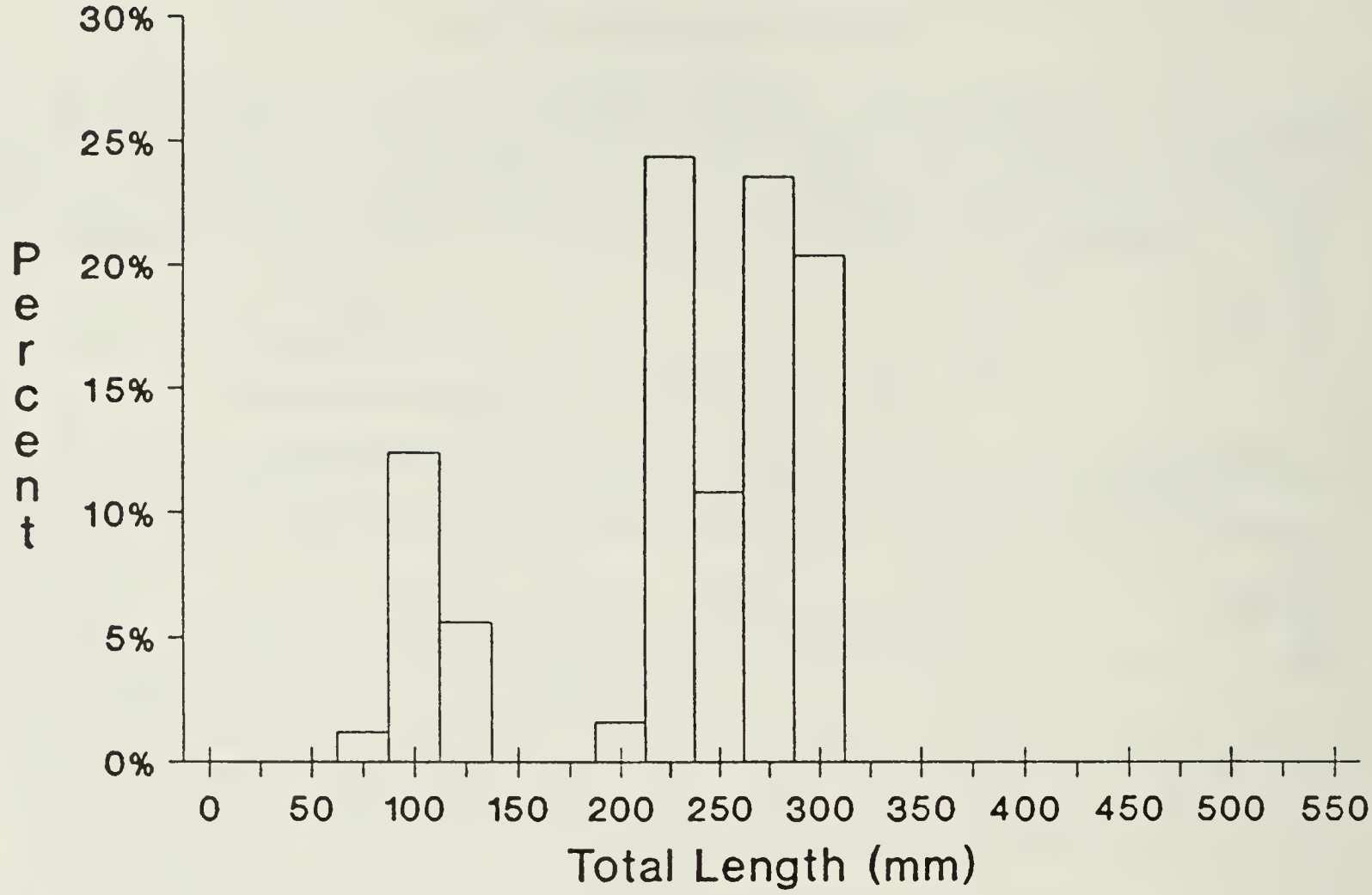

Figure 3. Length-frequency distribution of 250 largemouth bass captured from Petersen's Pond in 1981.

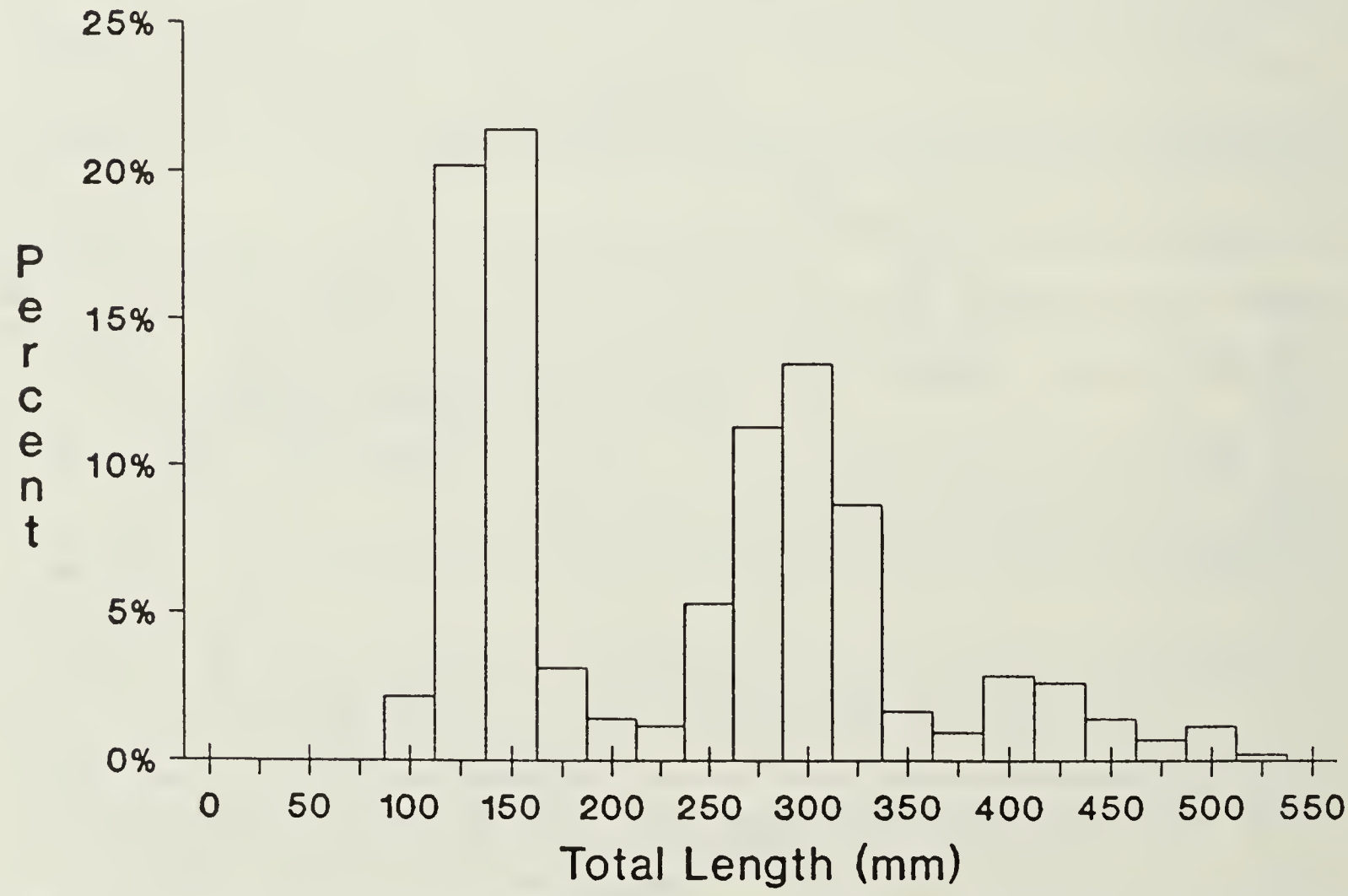

Figure 4. Length-frequency distribution of 416 largemouth bass captured from Knapp's Pond in 1981.

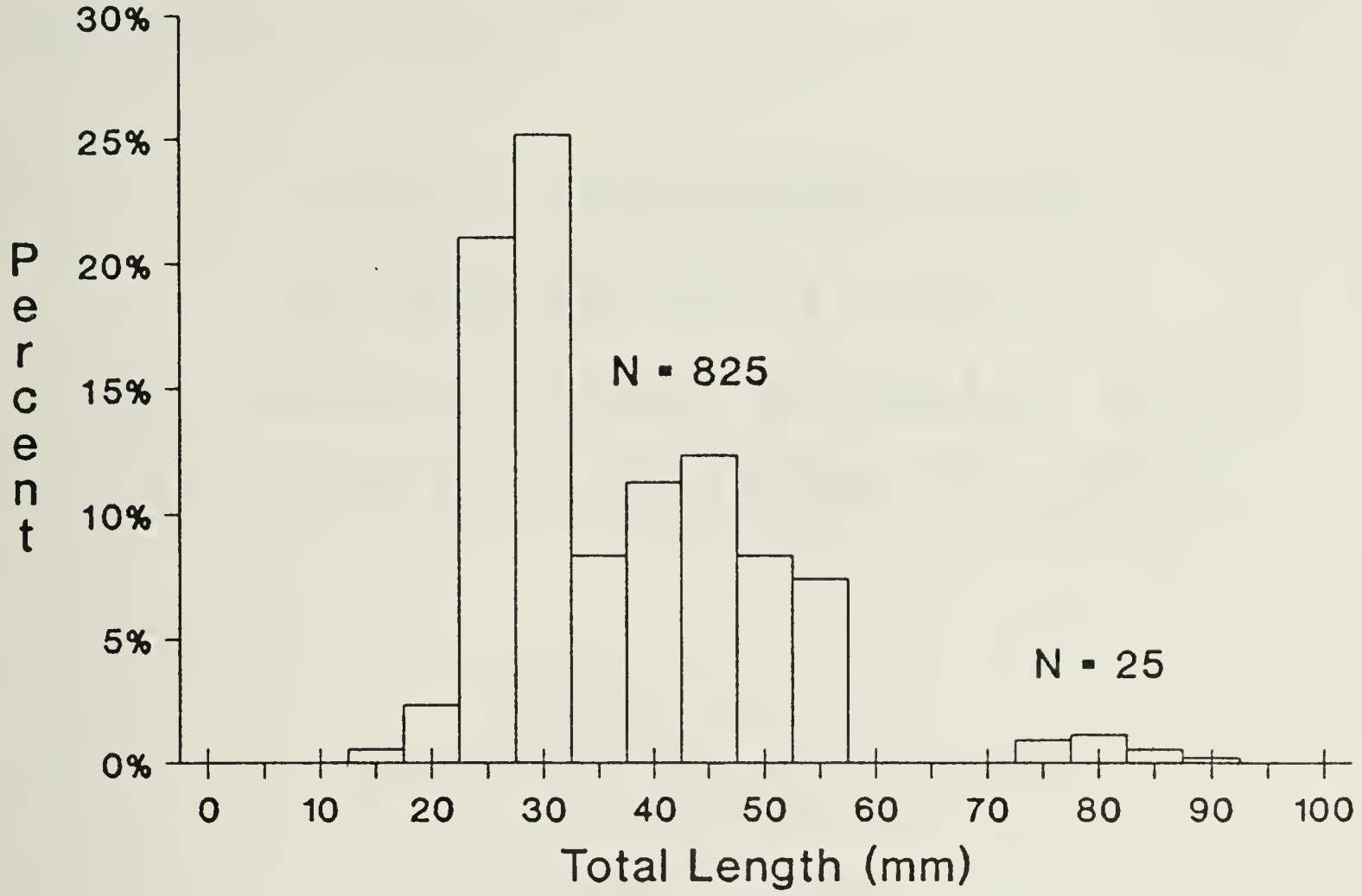

Figure 5. Length-frequency of 850 inland silverside recovered in October, 1980, from a pond stocked with 200 fry in June.

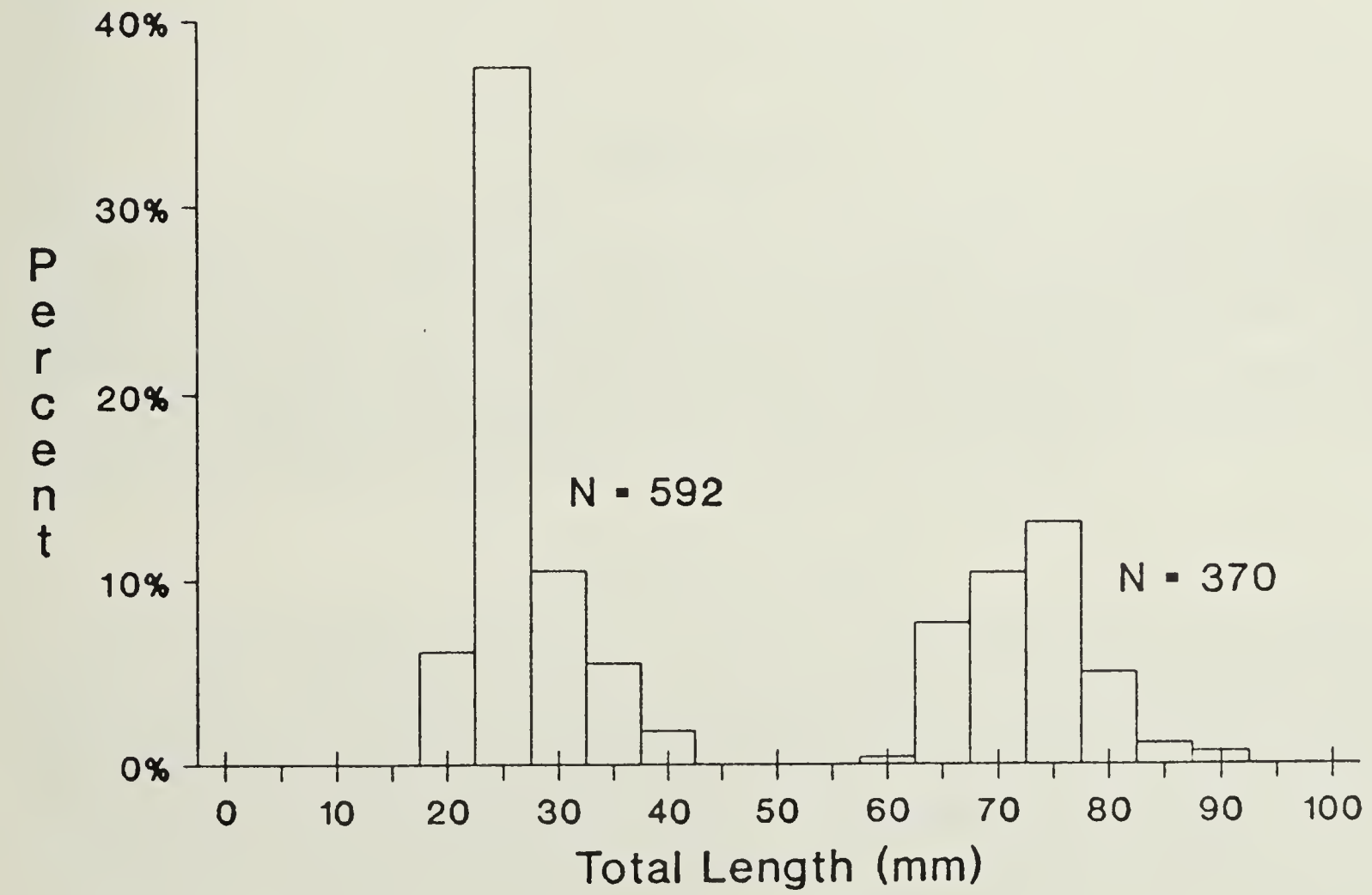

Figure 6. Length-frequency of 962 inland silverside recovered in October, 1981, from a pond stocked with 400 fry in June.

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FISH DISTRIBUTION IN RICHLAND CREEK, AN URBANIZING STREAM BASIN IN SOUTHWESTERN ILLINOIS

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ABSTRACT

Richland Creek drains 238 square miles of the Greater St. Louis Metropolitan Area in southwestern Illinois. It is subject to mine runoff, urban, and agricultural pollution. A total of 27 fish collections made in the basin included 32 species. The main channel is degraded but Prairie du Long Creek retains six species characteristic of good quality, high gradient streams. Records of the slender madtom and orangethroat darter are significant range extensions in Illinois.

INTRODUCTION

Richland Creek basin drains parts of Monroe, Randolph, and St. Clair counties in southwestern Illinois (FIGURE 1). It is some 28 miles long, nine miles wide, and drains approximately 238 square miles. Richland Creek itself has been channelized for 12 miles below Belleville (Lopinot, 1971) and now flows 38.4 miles in a southerly direction to join the Kaskaskia River Canal near Canal Mile 22 in Randolph County.

Part of the area along Richland Creek lies in the extreme southwestern portion of the Springfield Plain, and part in the Mt. Vernon Hill Country; both subdivisions of the Till Plains Section in the Central Lowland Province. Geomorphology of both

Springfield Plain and Mt. Vernon Hill Country is largely bedrock controlled. The Mt. Vernon Hill Country is dissected by streams and has few broad uplands. The Springfield Plain includes flat areas with shallow stream entrenchment, as well as areas with linear drift and isolated mounds of eroded drift (Leighton *et al.*, 1948).

Most of the Richland Creek system is typical of Illinois prairie streams flowing through areas of glacial till; with somewhat turbid water, and substrate of silt, mud, and sand with some gravel. However, reaches of Prairie du Long Creek, especially Kopp and Rockhouse Creeks, have eroded to bedrock and are more like Ozark streams (Pflieger, 1971, 1975), with clear water, and bedrock, boulder, sand, and gravel substrates.

The basin is recognized as one of the major potential urban development areas within the greater St. Louis Metropolitan Area. Approximately 5.7% of the basin is presently urbanized (U.S. Army Corps of Engineers, 1984). Existing urban development, including the communities of Belleville, Swansea, O'Fallon, and Shiloh, is concentrated in the upper portion of the basin. This primary zone of development in the northern basin is part of the advancing, urbanizing front of the metropolitan area. The basin is heavily utilized for row crops and pastureland and has a history of coal mining operation. Various portions of the drainage are thus subjected to different combinations of urban runoff, domestic sewage, agricultural runoff, and mine drainage.

Unfortunately, the basin was not sampled by Forbes and Richardson (1908) and long-term historical comparison of fish faunas thus is not possible. The first recorded scientific fish collections in the basin were made at four localities by personnel of the Illinois Natural History Survey and Department of Conservation at various times from 1959 through 1968. A total of 20 species was taken. These records were included on Smith's (1979) distribution maps for Illinois fishes.

In 1982 the Illinois Department of Conservation made six rotenone collections, totaling 4,103 fishes. In 1983 we made 21 seine collections, totaling 7,246 specimens. These collections show that, although the basin has been highly modified, and fish kills are not unusual, it still supports, particularly in Prairie du Long Creek, a surprisingly rich fish fauna which includes at least 32 species. We can hope that this information on distribution of fishes in the basin will contribute to rational development of the basin, to preservation and even enhancement, of its aquatic habitats.

MATERIALS AND METHODS

We made 21 collections (FIGURE 1, TABLE 1), comprising 7,246 fishes representing 30 species and one hybrid combination, between 27 June and 12 August 1983. Collections were made using either a 10 by 6-foot nylon 3/16-inch Delta mesh seine or a 15 by 4-foot nylon ¼-inch Delta mesh seine, or both, during daylight hours.

Data supplied by the Illinois Department of Conservation on six 1982 rotenone collections are included in FIGURE 1 and TABLE 1. These collections totaled 4,103 specimens representing 27 species and compliment our collections, which were concentrated in smaller tributaries. Data are presented on 11,349 specimens representing 32 species and one hybrid combination. Scientific and common names follow Robins *et al.*, (1980). Site data for these collections are given below.

COLLECTION SITES

Collection sites have been located by road crossings or direction and distance to nearest town or landmark. Date of collection follows each locality and the total number of fishes collected is given in parenthesis. A brief aquatic habitat description of the collection site and pertinent comments follow.

Richland Creek Main Channel

1. Richland Creek at Old Collinsville Road; 27 June 1983, (2), water murky with red stained banks, flow one cfs, bottom gravel size coal and silt over clay, width 12 to 15-feet, depth to 2½ feet, instream cover trash (wood), roots, and some undercut banks, forested overstory provided shade, observed dead ten-inch black bullhead, seined 25 minutes.

2. Richland Creek at Highway 159-158 interchange; 27 June 1983, (19), water clear with strong sewage odor, flow three to four cfs, bottom mud to rubble, width 15 to 20-feet, depth to three-feet predominantly one to 1½ feet, instream cover trash with some willow roots and undercut grass banks. Observed dead: Three black bullheads, one largemouth bass (one-foot), one green sunfish, seined 45 minutes.

3. Richland Creek at J19 west of Douglas; 27 June 1983, (12), water murky with strong sewage odor, flow 10-12 cfs, bottom mud with some gravel, width to 25-feet, depth to three-feet, predominantly 1½ to 2-feet, filamentous algae present, stream previously channelized, little instream cover and no overhead cover, seined 30 minutes.

4. Richland Creek at Illinois Department of Conservation (IODC) rotenone sampling station; T 1S, R 8W, Section 34, 5 August 1982, (63).

5. Richland Creek at IODC rotenone sampling station; T 2S, R 8W, Section 3, 5 August 1982, (1,237).

6. Richland Creek at IODC rotenone sampling station; T 2S, R 8W, Section 27, 27 July 1982, (1,415).

7. Richland Creek at IODC rotenone sampling station; T 3S, R 8W, Section 15, 29 July 1982, (279).

8. Richland Creek near Long Lake; 12 August 1983, (296), water turbid with sewage odor, flow ten cfs, bottom clay with rubble under bridge, width 40 to 50-feet, depth to four-feet average 2½ feet, stream previously channelized, instream cover fallen trees, logs and some roots, large number of *Gambusia* caught in two small backwater areas, seined 30 minutes.

Wolf Creek

9. Wolf Creek at Old Smelter Road; 27 June 1983, (105), water murky, flow one cfs, bottom gravel and mud, width 3 to 10-feet, depth one to 1½ feet, instream cover sparse with some roots, grass, limbs and logs, overhead cover 100%. *Notemigonus, Catostomus, Lepomis gulosus, Ictalurus punctatus,* and large *Ictalurus melas* were captured in a bridge culvert (50-feet long, 8-feet wide, 2½ feet deep with a concrete bottom covered with mud), seined one hour.

Douglas Creek

10. Douglas Creek on Douglas Road (J19) west of Highway 159; 27 June 1983, (272), flow two cfs, bottom mud, sand and fine gravel, width 5 to 20-feet, depth generally less than one-foot, instream cover roots, overhead cover nearly 100%, seined 45 minutes.

11. Douglas Creek at Press Road southeast of Smithton; 27 June 1983, (139), water green and murky, sewage odor with white foam on water, flow two cfs, bottom clay and sand with some gravel, predominantly pools with chutes, width 5 to 20-feet, depth to three-feet — one-foot average, little instream cover with some roots, overhead cover nearly 100% except near bridge, seined 45 minutes.

Kinney Branch

12. Kinney Branch at road ½ mile from Richland Creek; 28 June 1983, (149), water murky, flow less than one cfs, bottom clay, mud, sand with some rock, width to ten-feet, depth less than two-feet, instream cover grass overhang and some roots, seined 40 minutes.

West Fork

13. West Fork at P-57 south of intersection with P-66; 10 August 1983, (339), water clear, flow less than one cfs, bottom bedrock, clay, sand and gravel, width to 20-feet, depth to three-feet average 1½ feet, instream cover overhanging trees, roots, logs and grass along bank, seined 1½ hours.

14. West Fork at County Road P-60 approximately four miles southeast of Millstadt; 10 August 1983, (570), water flow less than one cfs, bottom gravel with some mud, width to 30-feet, depth to four-feet — average two-feet, instream cover tree roots, logs and undercut banks, seined 50 minutes.

15. West Fork at Highway 159; 28 June 1983, (206), water highly turbid after rain, flow five cfs (after rain), bottom sand and silt, width 15 to 30-feet, depth to four-feet — average 1½ feet, instream cover logs, cut bank and overhanging grass, seined 50 minutes.

16. West Fork at IDOC rotenone sampling station; T 2S, R 8W, Section 15, 9 August 1982, (636).

Prairie du Long Creek

17a. Prairie du Long Creek on P-57 approximately five miles south of Millstadt; 10 August 1983, (343), flow one cfs, bottom: Long sandy stretch with areas of sand and large rocks, width to 40-feet — average 20-feet, depth to 2½ feet — average one-foot, instream cover rocks and some tree roots, seined one hour.

17b. IDOC rotenone sampling station, 28 July 1982, (475).

18. Prairie du Long Creek ¾ miles southeast of Floraville; 11 August 1983, (717), water clear, flow two cfs, bottom predominantly sand, with sand and gravel, width to 20-feet, depth to four-feet — average two-feet, well developed pool and riffle sequences, instream cover undercut banks and grass overhang, seined 55 minutes.

19. Prairie du Long Creek at Club Congress Road; 10 August 1983, (175), water flow two to three cfs, bottom sand, gravel, and some mud, width to 20-feet —average ten-feet, depth to five-feet — average two-feet, instream cover roots and rocks, seined 45 minutes.

20. Prairie du Long Creek at Highway 156; 12 August 1983, (41), water turbid, little current, width 30-feet, depth to five-feet, bottom sand and clay with mud shoreline, site appeared to have been channelized, instream cover numerous logs and some overhanging grass, seined 30 minutes.

21. Prairie du Long Creek at Highway 159 south of Hecker; 12 August 1983, (104), water turbid, three cfs, width to 20-feet, depth to three-feet — average two-feet, instream cover considerable roots, logs, debris making seining difficult, seined 45 minutes.

Gerhardt Creek

22. Gerhardt Creek at St. Clair-Monroe County line; 10 August 1983, (425), water flow one cfs, bottom predominantly rock and sand with some mud, width to 30 feet — average 15-feet, depth to three-feet, pool riffle sequence, instream cover undercut roots, many crayfish caught in each seine haul, seined 44 minutes.

Kopp Creek

23. Kopp Creek on Kopp Road; 11 August 1983, (699), water clear, very little flow, bottom bedrock and bedrock with mud layers and sand; rock and gravel riffles, width to 20-feet, depth to two-feet — average one-foot, pool and riffle sequence, little instream cover, seined 45 minutes.

Walters Creek

24. Walters Creek at Klein School Road; 11 August 1983, (1,368), water clear, little flow, bottom bedrock with some mud over bedrock, width 10 to 15-feet, depth to two-feet — average less than one-foot, predominantly pools with short riffles, instream cover rocks and overhanging grass and roots, seined 40 minutes.

Rockhouse Creek

25. Rockhouse Creek at Highway J crossing; 11 August 1983, (1,072), water clear, flow one cfs, bottom bedrock with rocks, riffles gravel and rock, width to 30-feet, depth to two-feet — average one-foot, instream cover rock overhangs and some roots, seined 50 minutes.

Black Creek

26. Black Creek at Brickley Road northeast of Red Bud; 12 August 1983, (193), water clear to murky with strong sewage smell, little flow, bottom firm clay, sand, mud, and gravel, width 30 to 40-feet below bridge — to 15-feet above bridge, depth to three-feet below bridge — to 1½ feet above bridge, instream cover roots and considerable trash, seined 20 minutes.

RESULTS

Smith's (1979) distribution maps show 20 species occurring at four localities in Richland Creek. The collections reported here bring the list of fishes known from Richland Creek to 33 species. Smith (1979) reported bigmouth buffalo, *Ictiobus cyprinellus,* which was not found in either subsequent sampling effort.

The most numerically abundant fishes found in this study were the minnows *Semotilus atromaculatus,* (16% of total fishes, 20 sites) and *Pimephales notatus* (12%, 11 sites). Creek chubs were generally distributed throughout the drainage, except for upper Richland Creek. They tended to be relatively more abundant in headwater streams. Bluntnose minnows prefer hard bottomed pools in creeks and small rivers (Smith, 1979). This is reflected in our collections. All but 17 specimens were from the upper tributaries of Prairie du Long Creek.

Mosquito fish, *Gambusia affinis,* (11%, 10 sites) was third in total abundance. It was concentrated in lower parts of the drainage in shallow slack water habitat.

Red shiners, *Notropis lutrensis,* (10%, 21 sites) were widespread throughout the drainage, except for upper Richland Creek. Fathead minnows, *P. promelas,* (9.6%, 14 sites) although widespread in the drainages, were concentrated in the lower part of the main channel. Bigmouth shiners, *Notropis dorsalis,* (8.7%, 17 sites) were generally abundant in the tributaries and present in the lower main channel. The central stoneroller, *Campostoma anomalum,* (8.8%, 16 sites) was most abundant in the upper parts of Prairie du Long and West Fork of Richland Creek. Together these six minnows and the mosquito fish made up 65.2% of the total fishes collected.

Green sunfish, *Lepomis cyanellus,* (6.9% of total numbers, 22 sites) and bluegill, *Lepomis macrochirus,* (2.2%, 22 sites) were the most widespread species.

Blackstripe topminnows, *Fundulus notatus,* occurred at 17 sites scattered throughout the state. The common bullhead in the system was the yellow bullhead, *Ictalurus natalis,* 3.3% of the total, taken at 16 sites. White suckers, *Catostomus commersoni,* occurred at 16 sites scattered throughout the basin, but were more abundant in the western tributaries. Two minnows, *Phenacobius mirabilis* and *Notropis umbratilis,* each occurred at 15 sites, primarily in the western tributaries. The redfin shiner made up 2.1% of the total fish caught.

Seven species were taken only in Prairie du Long Creek and its tributaries. Six of these are species normally associated with clear high-gradient streams with sand, gravel, and bedrock substrate; *Moxostoma erythrurum, Noturus exilis, Lepomis megalotus, Percina caprodes, Etheostoma spectable,* and *E. nigrum.* The flier, *Centrarchus macropterus,* was taken in the lower base-level portion of the creek.

DISCUSSION

The three most significant causes of water quality degradation in the Richland Creek Basin are acid mine drainage, sewage treatment plant discharge, and agricultural runoff. These factors appear in sequence as one travels downstream from the northern to the southern regions of the Richland Creek Basin (Versar Inc., 1980).

Acid mine drainage, principally from abandoned coal mines in the northern headwaters, causes extremely high levels of iron, manganese, sulfates, and dissolved solids in the northern part of Richland Creek. These effects were observed, to a lesser extent, all the way to the creek's confluence with the Kaskaskia River. We

have seen the headwaters running blood red after a storm event, and ferric hydroxide precipitate coated the stream banks at the confluence with the Kaskaskia River.

Sewage treatment plant (STP) discharges are the only major point sources in the Basin. Most of the eight STP discharges are located near the Belleville and Swansea area. More than six million gallons/day (ten cfs) are discharged from the Belleville area. Thus, the water flow down to the confluence with Douglas Creek is often mostly treated water and the effects of these discharges are evident downstream of Belleville. Elevated levels of fecal coliforms, ammonia, total Kjeldahl nitrogen, nitrate, orthophosphate, and total phosphorus occur downstream of Belleville, and historical data indicate that during low summer flows, Richland Creek is occasionally almost anaerobic in this area. Douglas Creek receives discharges from Millstadt and Smithton, and Kinney Branch receives discharges from Freeburg (Versar Inc., 1980).

Much of the remainder of Richland Creek Basin is impacted by agricultural runoff, which results in high concentrations of microbes, nutrients, and suspended solids. During our work in the basin, we saw many examples of the worst possible agricultural practices: Fields plowed to the channel edge; and row crops planted on steep slopes with the rows running straight downhill to huge erosion gullies.

Urban runoff from Belleville probably also degrades Richland Creek, but its effects are difficult to isolate due to the polluted character of the creek in this reach. A few housing developments are already scattered throughout the basin, and problems with urban runoff will undoubtedly increase with time.

The number of fish species collected per site reflects water quality conditions, and was generally low in the highly polluted main channel and higher in smaller tributary streams. The worst sites were in the main channel above its confluence with Douglas Creek (TABLE 1).

The distribution and abundance of *Pimephales promelas* and *P. notatus* in Richland Creek reflected the stream's pollution pattern. *P. promelas* was more abundant than *P. notatus* in the polluted main channel, but *P. notatus* was more abundant in the tributary streams where *P. promelas* rarely occurred. Pflieger (1975) noted that *P. promelas* was tolerant of high temperatures, extreme turbidity, and low oxygen. Keevin (1978) found *P. promelas* to be the most abundant species in the polluted urban streams of St. Louis and St. Louis County regardless of stream bottom type. Smith (1979) noted that *P. promelas* is usually abundant where *P. notatus* is absent, suggesting that it cannot compete successfully with species of similar habitat.

Prairie du Long Creek and its tributaries contain seven species not found by us in the main channel. Six of these species were characteristic of high quality streams. Two species, *Noturus exilis* and *Etheostoma spectabile*, represent range extensions in the Kaskaskia River basin. *N. exilis* was previously known only from the headwaters, and *E. spectabile* from only two tributaries in the middle reaches of the Kaskaskia River (Smith, 1979).

Land owners in the Prairie du Long basin told us that fish kills were not uncommon. Much of the basin has poor soil management practices such as row crops planted on steep slopes. Nevertheless, the fish fauna reflects the Ozark-like rugged natural beauty of the area. We strongly urge planners and developers to recognize and preserve this aesthetic resource.

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LITERATURE CITED

Forbes, S.A. and R.E. Richardson. 1908. The fishes of Illinois. Illinois State Laboratory of Natural History. cxxxi + 357 p. plus separate atlas containing 102 maps.

Keevin, T.M. 1978. A distributional and faunistic analysis of the small stream fishes of St. Louis and St. Louis County, Missouri. Masters Thesis, Southern Illinois University-Edwardsville. 118 pp.

Leighton, M.M., Ekblaw, G.E., and L. Horberg. 1948. Physiographic Divisions of Illinois. J. Geol. 56(1): 16-33.

Lopinot, A.C. 1971. Channelized streams and ditches of Illinois. Illinois Department of Conservation, Special Fisheries Report No. 35, 59 p.

Pflieger, W.L. 1971. A distributional study of Missouri fishes. University of Kansas Museum of Natural History Publications 20(3): 225-570.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation. viii + 343 p.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. American Fisheries Society Special Publication No. 12. 174 p.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 304 p.

U.S. Army Corps of Engineers. 1984. Richland Creek, Illinois: Flood control study feasibility report (12174). 25 p.

Versar, Inc. 1980. Surface water quality investigation of the Richland Creek, Illinois Basin. Final Contract Report to the St. Louis District, U.S. Army Corps of Engineers. Various page numbers.

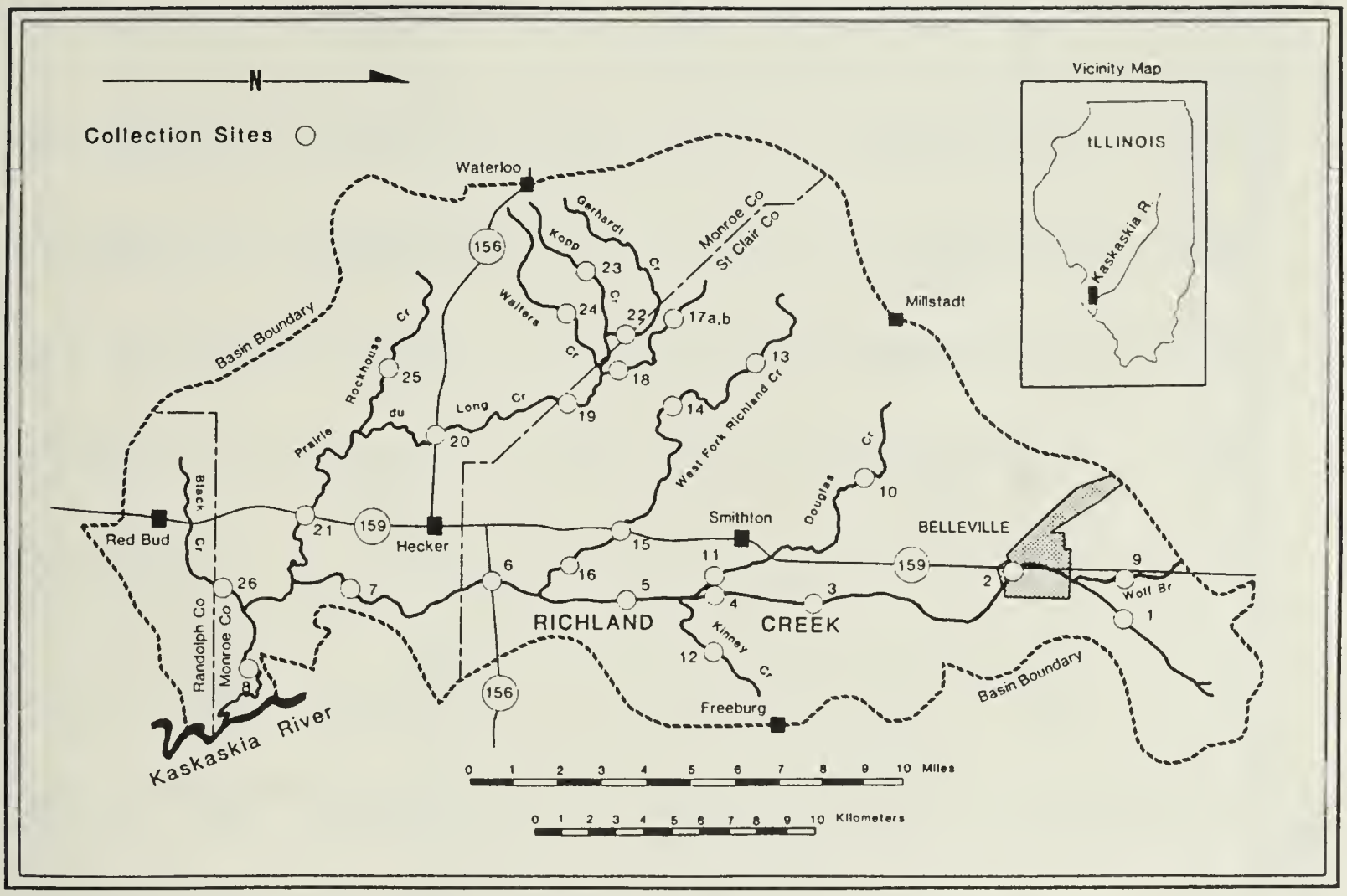

Figure 1. Location of fish sampling sites.

Table 1. Fishes collected from Richland Creek (Number of Individuals)

SITE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dorosoma cepedianum	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Cyprinus carpio	—	—	—	—	—	—	10	—	—	—	—	—	—	—
Notemigonus crysoleucas	—	1	1	—	3	—	1	—	10	—	—	2	—	—
Semotilus atromaculatus	—	—	—	9	132	144	33	22	—	61	24	83	58	162
Phenacobius mirabilis	—	—	—	—	—	—	1	—	—	1	3	1	5	1
N. dorsalis	—	—	—	—	39	32	4	3	—	120	72	22	13	23
N. lutrensis	—	—	1	—	6	4	10	11	—	29	26	2	27	5
N. stramineus	—	—	—	—	4	—	2	—	—	12	3	—	—	—
N. umbratilis	—	—	—	—	—	—	—	6	—	4	1	—	—	24
Pimephales notatus	—	—	—	—	1	3	—	2	—	—	—	—	—	—
P. promelas	—	1	8	—	225	785	45	2	—	2	—	1	1	1
Campostoma anomalum	—	—	—	—	7	6	10	—	—	10	—	5	87	300
Moxostoma erythrurum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Catostomus commersoni	—	—	—	—	—	4	—	—	1	3	1	—	12	10
Erimyzon oblongus	—	—	—	—	—	2	—	—	—	—	—	—	4	—
Ictalurus melas	—	—	—	—	4	3	—	—	39	—	—	—	1	1
I. natalis	—	—	—	—	12	182	31	3	—	—	—	6	1	1
I. punctatus	—	—	—	—	—	1	—	—	1	—	—	—	—	—
Noturus exilis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aphredoderus sayanus	—	—	—	—	—	1	2	—	—	1	—	—	—	—
Fundulus notatus	—	2	—	1	36	3	1	1	—	4	1	—	—	—
Gambusia affinis	—	—	—	17	638	123	64	244	—	—	—	1	—	—
Micropterus salmoides	1	4	—	—	—	1	2	—	12	—	—	—	52	5
Lepomis cyanellus	—	11	1	31	117	113	—	1	6	21	3	20	58	11
L. gulosus	—	—	—	—	—	—	—	—	1	2	—	—	1	—
L. macrochirus	1	—	1	5	11	1	57	1	35	2	5	5	19	26

L. megalotus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Centrarchus macropterus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Percina caprodes	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Etheostoma gracile	—	—	—	—	1	7	1	—	—	—	—	—	—	—
E. nigrum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E. spectable	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L. macrochirus/														
L. cyanellus hybrid	—	—	—	—	1	—	3	—	—	—	—	1	—	—
Total # Individuals	2	19	12	63	1,237	1,415	279	296	105	272	139	149	339	570
Total # Species	2	5	5	5	15	18	17	11	8	14	10	11	14	13

Table 1 (Continued). Fishes collected from Richland Creek (Number of Individuals)

SITE NUMBER	15	16	17a	17b	18	19	20	21	22	23	24	25	26	Total
Dorosoma cepedianum	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Cyprinus carpio	—	—	—	—	—	—	—	—	—	—	—	—	—	10
Notemigonus crysoleucas	—	—	—	—	—	—	—	—	—	—	—	—	—	18
Semotilus atromaculatus	26	179	65	139	84	7	—	—	72	280	65	140	29	1,814
Phenacobius mirabilis	3	19	6	—	4	4	—	—	13	—	2	30	3	96
N. dorsalis	—	7	53	1	174	—	—	—	8	81	218	97	17	984
N. lutrensis	95	9	153	16	134	91	8	19	99	2	48	340	—	1,135
N. stramineus	—	—	3	—	7	—	—	—	5	—	—	14	—	50
N. umbratilis	20	5	27	2	23	17	11	14	24	—	46	5	5	234
Pimephales notatus	—	11	5	—	83	4	—	—	70	79	832	274	—	1,364
P. promelas	—	2	—	—	—	—	—	—	—	—	2	1	19	1,095
Campostoma anomalum	3	45	5	83	83	1	—	—	42	222	76	17	—	1,002
Moxostoma erythrurum	—	—	—	—	—	—	—	—	8	—	—	14	—	22
Catostomus commersoni	4	17	1	33	1	1	—	1	14	7	4	3	—	117
Erimyzon oblongus	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Ictalurus melas	2	25	—	2	—	—	—	3	—	—	—	—	—	80
I. natalis	1	91	3	25	3	1	—	—	2	1	—	14	2	379
I. punctatus	—	—	—	1	—	—	—	—	—	—	—	—	—	3
Noturus exilis	—	—	2	1	—	—	—	—	9	—	6	7	—	25
Aphredoderus sayanus	—	1	—	—	—	—	—	—	—	—	—	—	1	6
Fundulus notatus	3	26	—	—	14	5	7	3	—	—	1	6	3	117
Gambusia affinis	—	—	—	—	—	—	—	53	1	—	—	3	104	1,248
Micropterus salmoides	—	1	—	8	—	1	—	—	2	—	—	—	—	89
Lepomis cyanellus	42	183	4	71	3	3	—	1	3	11	4	—	10	785
L. gulosus	—	—	—	—	—	—	—	—	—	—	—	—	—	4
L. macrochirus	5	4	2	19	17	15	13	4	16	—	—	42	—	249

L. megalotus	—	—	2	3	6	7	2	1	—	—	—	—	—	21
Centrarchus macropterus	—	—	—	—	—	—	—	4	—	—	—	—	—	4
Percina caprodes	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Etheostoma gracile	—	9	—	—	—	—	—	—	—	—	—	—	—	18
E. nigrum	—	—	12	71	81	16	—	—	25	13	63	54	—	335
E. spectable	—	—	—	—	—	2	—	1	12	3	1	10	—	29
L. macrochirus/														
L. cyanellus hybrid	2	—	—	—	—	—	—	—	—	—	—	—	—	7
Total # Individuals	206	634	343	475	717	175	41	104	425	699	1,368	1,072	193	11,399
Total # Species	11	17	15	15	15	15	5	11	18	10	14	19	10	32

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FISHES IN THE ILLINOIS PORTION OF THE UPPER DES PLAINES RIVER

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ABSTRACT

The composition and relative abundance of fish species in the upper portion of the Des Plaines River are reported. Ninety percent of the fish biomass in this section of the river is carp. Standing crop estimates of carp indicate 371 kg/km of river.

INTRODUCTION

The Des Plaines River Wetlands Demonstration Project is the reconstruction of a riverine wetland on a 182 ha site bordering a 4.67 km stretch of the Upper Des Plaines River, downstream from Wadsworth Road. The site is in Wadsworth, Illinois, Lake County, 58 km north of Chicago. The river, which drains a 5,400 square km watershed (80% of which is agricultural and 20% urban), is polluted with non-point source contaminants from both urban and agricultural activities. Portions of the stream bed have been channelized, the banks cut steep, and floodplains leveed and, as a result, homes downstream are subject to periodic flooding. The site has been drained with tile fields and mined for gravel, causing the original wetland, prairie species to be disturbed, destroyed, or replaced with plant communities dominated by Eurasian or weedy native species and degraded or depleted animal communities.

The construction phase of the demonstration project, which started in 1986, will regrade and broaden the stream channel, carving terraces and experimental wetland areas out of the adjoining land surface. Streamflow will be pumped to the site perimeter and allowed to gradually return to the channel. The duration and extent of contact between land and water will be varied by sluice gates, in accor-

dance with research programs. Native plant communities will be introduced, spawning and breeding areas created, and native fish and wildlife attracted back to the site.

As part of this project a literature search was conducted to determine the species of fish known to have been present in the Illinois portion of the upper Des Plaines River watershed. In addition, the literature was used to postulate the fish assemblage during the pre-settlement era. A baseline fish survey was made in 1985 and 1986. The common and scientific names of fishes mentioned in this report follow those listed in Robins et al. (1980).

METHODOLOGY

Current Fish Survey

The existing fish populations in the experimental area of the Des Plaines River and Mill Creek were sampled in May and June 1985 and September and November 1986. The fish community in the Des Plaines River was sampled by electrofishing, gillnetting, trapnetting, and seining. Sampling effort was intense considering the size of the body of water involved. The 4.67 km stretch of the Des Plaines River was electrofished for 238 minutes in 1985 and 189 minutes in 1986. In 1985 and 1986, 3 experimental gillnets were set overnight for 12 hours. In 1985, 2 trapnets and in 1986, 4 trapnets were set overnight for 12 hours. In 1985, 21 seine hauls and in 1986, 31 seine hauls were made.

Electrofishing equipment consisted of a boat-mounted 3500 watt, three-phase generator with a balanced electrode array (Novonty and Priegel, 1974). Seining was done with an 8-m-long, 2-m-deep seine having a 3.2-mm bar mesh. The trapnets were 1.8 m long by 0.9 m rectangular frame nets with 13-mm bar-mesh netting. The first throat of the nets consisted of a vertical slit, and the second throat was circular. Each net was equipped with a single 15 m lead originating from the center of the net. Each experimental gillnet was 45 m long, with five 9 m panels of 12.7 mm, 25.4 mm, 38.1 mm, 50.8 mm, and 63.5-mm bar-mesh netting.

From 7 September through 11 September 1986, during a period of low flow, two block nets of 1.3 cm square mesh were placed across the Des Plaines River. Each block net was approximately 22.7 m long and 6.1 m deep. The nets were set in a section of the river that had a maximum depth of approximately 0.9 m. The nets were weighted with at least 3 kg of chain/meter. Ten-centimeter-diameter floats 28 cm long were placed approximately 30 cm apart. Metal fence poles were also used to elevate the nets above the water, although an area was left so that canoes could go over the nets by submerging the floats. We are confident that common carp could not move past these barriers. Leaves and other debris were removed from the nets at least four times each day. The two block nets were placed across the river 1,440 m apart. The upstream net was approximately 60 m below the confluence of Mill Creek and the Des Plaines River, and the downstream net was placed approximately 545 m upstream from where the river enters the South Economy Gravel Pit.

The standing stock of carp between the two block nets was estimated by the depletion method (Ricker 1975), which correlates catch-per-unit effort with summation of catch. The correlation produced is extrapolated to zero catch, at which point the summation of catch is the theoretical population estimate. This method

assumes all fish are equally vulnerable to the sampling devices and no immigration or emigration of fish occurs. In addition, in order to obtain a meaningful estimate it is usually necessary to remove at least 50% of the fish population. In this study one unit of effort each day consisted of two electrofishing runs between the two block nets and the catch of 12 hoop nets set for approximately 24 hours. An effort was made to pick up and remove as many carp as possible on each shocking run. The hoop nets were 1.2 m in diameter, double throated, 4.8 m long, 7 hoop, 5.1 cm square mesh with two 7.6 m wings. All hoop nets were set facing downstream at approximately 130 m intervals. One net was placed immediately below the upper block net. Since the Des Plaines River was only about 14 m wide, the wings on these nets were placed from bank to bank. The 1.2-m-deep leads were deeper than the water in the river.

RESULTS AND DISCUSSION

Twenty-one species of fish were collected in 1976 and in 1983 from the section of the Des Plaines River that flows through the demonstration site; 31 species were collected in 1985; and 28 species were collected in 1986 (Table 1). Since 1976, 36 species have been found on the wetlands demonstration site. Five species (central mudminnow, goldfish, quillback, stonecat, brook stickleback) that were collected in 1985 were not found in 1986. However, two species, the spotted sucker and Iowa darter that were found in 1986 had not been reported from the Des Plaines River in 1976, 1983, or 1985 (Table 1).

The spotted sucker was known to be in Mill Lake Gravel Pit and the North Economy Gravel Pit, but it was not reported from the South Economy Gravel Pit by an Illinois Department of Conservation survey in 1975 or Heidinger (1985). At the time of the 1986 sample, the Des Plaines River had been cut through the South Economy Gravel Pit. The Iowa darter was not found in samples from the Illinois section of the upper Des Plaines River in 1967 (Muench, 1968), 1976 (Brigham et al., 1978) or 1985. It was found in the upper Des Plaines River in Kenosha County, Wisconsin, in 1979-1980 (Southern 1980).

There was little change in the relative abundance by number or weight of the fishes collected in 1985 versus 1986 (Table 2). Numerically, the spotfin shiner and sand shiner were the most abundant. As a percentage of fish collected, the seven most abundant species in 1985 were the spotfin shiner (24.9), sand shiner (18.9), common carp (17.8), green sunfish (8.4), black bullhead (6.4), golden shiner (4.4), and bluegill (3.0), which comprised almost 84% of the sample (Table 2). In 1986 the spotfin shiner (36.2), sand shiner (23.0), common carp (10.5), bluntnose minnow (9.9), bluegill (4.1), green sunfish (3.7), and blackstriped topminnow (3.5), comprised 90.9% of the sample (Table 2). These relative abundance values must be used with care. Combining the catch of all sampling methods tends to skew the actual relative abundance of the fish population. For example, almost all of the minnows were collected by seining, while the majority of the carp were collected by electrofishing. Future comparisons are valid only if the same ratio of effort exists among the various types of sampling equipment.

Number, mean length, mean weight, and coefficient of condition (K) at each age for twelve species are listed in Table 3. K is equal to the weight in grams of a fish times 100 divided by the total length in centimeters cubed.

A total of 384 carp weighing 515.3 kg was removed from the area between the two block nets (Table 4). These fish averaged 1.34 kg. The catch on September 9 was slightly greater than the catch on September 8; this indicates gear saturation. Two depletion estimates can be made using this data set. If the catch from all four days is used in the calculation, the depletion estimate is 550.2 kg with an r^2 equal to 0.52. If only the last three days' data are used, the estimate is 530.3 kg yielding a r^2 equal to 0.97. At the time the sample was taken there was approximately 1.98 ha of water, or 1.48 km between the block nets. Based on the depletion estimate of 550.2 kg, there was 277.9 kg of carp per hectare or 371 kg per kilometer.

It would have been desirable to continue the removal process for several more days, but heavy rains and increased flow rates made it impossible to maintain the hoop nets or the block nets.

Historical Records

Based on the literature search by Brigham et al. (1978) and the 1985 and 1986 survey, at least 62 species of fish occurred in the Illinois portion of the upper Des Plaines River watershed (Tables 1, 5, and 6). This watershed is a much larger and more diverse habitat than is found on the wetlands demonstration project site. In 1967, 28 species and in 1976, 40 species were found (Table 5). The 20 species that were not found in 1976 are in nine different families of fish (Table 4). Of the 20 species not found, only the redear and brown bullhead are sport species. One species, the blacknose shiner, has been placed on the Illinois threatened fish species list (Smith and Page, 1981).

The historical data only give an indication of species occurrence. There are no data on age, growth rate, biotic indices, or condition factors. In addition, data are lacking on the numbers and species of fish removed by fishermen.

Pre-Settlement Fish Community

Since pre-settlement, many significant changes have taken place in the physical characteristics of the demonstration project site, as well as in the fish fauna of the Des Plaines River. During the pre-settlement era there was no ecological equivalent of the deep water habitat now found in the flooded rock quarries, and the Des Plaines River was very different from the way it is now. In pre-settlement times the river was shallow, clear, very slow-moving, and meandering, with low-lying areas merging into marshy wetlands. Today, channelization and floodplain filling to support either agricultural or urban development have resulted in loss of the riverine wetlands and the accumulation of spoil along the river banks. The resulting stream channels are narrower, the banks are steeper, and the floodplain is no longer a moist meadow.

To date at least 62 species of fish have been found in the Illinois portion of the upper Des Plaines River watershed (Table 1, 5, and 6). Other species, such as the longear sunfish (*Lepomis megalotis*), orangespotted sunfish (*L. humilis*), weed shiner (*Notropis texanus*), southern redbelly dace (*Phoxinus erythrogaster*) and blacknose dace (*Rhinichthys atratulus*), probably were present during the pre-settlement era. O'Brien (1964) found the remains of bass (*Micropterus* spp.), freshwater drum (*Aplodinotus grunniens*), gar (*Lepisosteus* spp.), and buffalo (*Ictiobus* spp.) in two late woodland archaeological sites near the Des Plaines River in Lake County. Only slightly less likely would have been the occurrence of the

longnose dace (*R. cataractae*), the northern redbelly dace (*P. eos*), and several other species of suckers. A number of other species may have been present also.

There is no direct proof that sport species such as the walleye (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieui*), and muskellunge (*Esox masquinongy*) were ever present in this system. Some species that are now found in the upper Des Plaines River were absent during pre-settlement. The common carp and goldfish were introduced into the United States from Europe. The redear probably was absent also, and it is doubtful that the channel catfish reproduced in this area.

In addition to a decrease in the number of species found in the Des Plaines River and, therefore, the diversity of the fish community, there has been a major change in the relative abundance of the various species, especially on a biomass basis. The common carp now makes up the majority of the fish biomass (approximately 90%). Historically, other species, such as the northern pike, were probably much more abundant.

By almost any measure, the fish habitat in the upper Des Plaines River has been seriously degraded since the pre-settlement era due to channelization, urbanization, and agricultural practices. This has led to a reduction in or loss of many pollution-sensitive species. At the same time, on a biomass basis the pollution-tolerant common carp has become very abundant.

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LITERATURE CITED

Bertrand, B. 1984. Des Plaines River basin fisheries assessment. Illinois Department of Conservation, Division of Fish and Wildlife Resources. 44 p.

Brigham, W.U., D.A. McCormick, and M.J. Wetzel. 1978. The watersheds of northeastern Illinois; quality of the aquatic environment based upon water quality and fishery data. Final report, Illinois Natural History Survey, Staff Paper No. 31. 251 p.

Heidinger, R.C. 1985. Fish. Pages 12-1 through 12B-11. *In* Donald L. Hey and Nancy Philippi (eds.), The Des Plaines River Wetlands Demonstration Project. Vol. II. Baseline survey. Wetlands Research Inc., Chicago, IL.

Muench, D. 1968. Upper Illinois tributaries and Des Plaines River basin. *In* A.C. Lopinot (ed.), Inventory of the Fishes of Nine River Basins in Illinois — 1967. Illinois Department of Conservation, Special Fishery Report No. 25. 34 p.

Novonty, D.W. and G.R. Priegel. 1974. Electrofishing boats: Improved design and operational guidelines to increase the effectiveness of boom shockers. Wisconsin Department of Natural Resources, Technical Bulletin 73. 48 p.

O'Brien, P.J. 1964. Two late woodland archaelogical sites in Lake County, Illinois. Transactions Illinois Academy Science 57(2): 109-115.

Ricker, W.E. 1985. Computation and interpretation of biological statistics of fish populations. J. Fish. Res. Bd. Canada Bulletin 191. 382 p. Ottawa, Canada.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes of the U.S. and Canada. Special Publication No. 12, American Fisheries Society, Bethesda, MD.

Southern, W.E. 1980. Habitat evaluation of the Upper Des Plaines River and adjacent wetlands, 1979-1980. Volume 1, Final Report by Environmental Consultants and Planners to U.S. Environmental Protection Agency, Region V, Chicago, IL 112 p.

Smith, P.W. and L.M. Page. 1981. Endangered and threatened fishes. Pages 5-20. *In* Bowles, M.L. et al. (eds.), Endangered and Threatened Species of Illinois, Illinois Department of Conservation.

Table 1. Fish species found in the upper Des Plaines River Wetlands Demonstration Project site.

Common name	Scientific name	Family	1976[1]	1983[3]	1985	1986
Central mudminnow	*Umbra limni*	Umbridae	–	–	+	–
Northern pike	*Esox lucius*	Esocidae	+	–	+	+
Grass pickerel	*E. americanus*	"	–	–	+	+
Goldfish	*Carassius auratus*	Cyprinidae	–	–	+	–
Common carp	*Cyprinus carpio*	"	+	+	+	+
Golden shiner	*Notemigonus crysoleucas*	"	–	+	+	+
Bigmouth shiner	*N. dorsalis*	"	–	–	+	+
Rosyface shiner	*N. rubellus*	"	+[2]	–	–	–
Spotfin shiner	*N. spilopterus*	"	+	+	+	+
Sand shiner	*N. stramineus*	"	+	+	+	+
Common shiner	*N. cornutus*	"	–	+	–	–
Bluntnose minnow	*Pimephales notatus*	"	+	+	+	+
Fathead minnow	*P. promelas*	"	–	+	+	+
White sucker	*Catostomus commersoni*	Catostomidae	+	+	+	+
Spotted sucker	*Minytrema melanopus*	"	–	–	–	+
Quillback	*Carpiodes cyprinus*	"	–	–	+	–
Black bullhead	*Ictalurus melas*	Ictaluridae	+	+	+	+
Yellow bullhead	*I. natalis*	"	+	–	+	+
Channel catfish	*I. punctatus*	"	+	–	+	+
Stonecat	*Noturus flavus*	"	–	+	+	–
Tadpole madtom	*N. gyrinus*	"	–	+	–	–
Blackstriped topminnow	*Fundulus notatus*	Cyprinodontidae	+	+	+	+
Yellow bass	*Morone mississippiensis*	Percichthyidae	+	+	+	+
Green sunfish	*Leopmis cyanellus*	Centrarchidae	+	+	+	+
Pumpkinseed	*L. gibbosus*	"	+	+	+	+
Warmouth	*L. gulosus*	"	+	–	+	+
Bluegill	*L. macrochirus*	"	+	+	+	+
Largemouth bass	*Micropterus salmoides*	"	+	+	+	+
White crappie	*Pomoxis annularis*	"	+	–	+	+
Black crappie	*P. nigromaculatus*	"	+	+	+	+
Johnny darter	*Etheostoma nigrum*	Percidae	+	+	+	+
Iowa darter	*E. exile*	"	–	–	–	+
Blackside darter	*Percina maculata*	"	+[2]	+	+	+
Yellow perch	*Perca flavescens*	"	–	+	+	+
Brook silverside	*Labidesthes sicculus*	Atherinidae	–	+	+	+
Brook stickleback	*Culaea inconstans*	Gasterosteidae	–	–	+	–
Total number of species			21	21	31	28

[1]Brigham et al. (1978).
[2]Species found in the demonstration project site, but only in Mill Creek.
[3]Bertrand (1984).

Table 2. Relative abundance (RA) by number and weight of fish collected from the Des Plaines River by all sampling methods.

	1985				1986			
Common name	Number	RA (%)	Weight (g)	RA (%)	Number	RA (%)	Weight (g)	RA (%)
Largemouth bass	4	0.7	522	0.4	12	1.0	586	0.4
Bluegill	18	3.0	498	0.3	48	4.1	800	0.6
Green sunfish	50	8.4	606	0.4	44	3.7	899	0.6
Yellow bass	6	1.0	310	0.2	5	0.4	176	0.1
Pumpkinseed	15	2.5	247	0.2	6	0.5	125	—
Black crappie	2	0.3	6	—	13	1.1	1,314	0.9
Yellow perch	2	0.3	14	—	2	0.2	49	—
Grass pickerel	1	0.2	88	—	3	0.2	214	0.1
Channel catfish	2	0.3	3,319	2.3	3	0.2	1,559	1.1
Stonecat	4	0.7	157	0.1	—	—	—	—
Quillback	1	0.2	2,155	1.5				
Yellow bullhead	3	0.5	372	0.2	6	0.5	729	0.5
Black bullhead	38	6.4	2,660	1.8	13	1.1	1,519	1.1
White sucker	4	0.7	1,259	0.9	5	.0.4	1,584	1.1
Common carp	106	17.8	132,080	90.0	122	10.5	123,565	87.8
Northern pike	3	0.5	2,311	1.6	6	0.5	6,204	4.4
Central mudminnow	4	0.7	8	—	—	—	—	—
Goldfish	1	0.2	261	0.2	—	—	—	—
Golden shiner	26	4.4	19	—	4	0.3	9	—
Bigmouth shiner	3	0.5	1	—	1	—	2	—
Spotfin shiner	148	24.9	118	—	421	36.2	358	0.2
Sand shiner	112	18.9	77	—	267	23.0	260	0.2
Bluntnose minnow	17	2.9	7	—	115	9.9	94	—
Fathead minnow	10	1.7	5	—	7	0.6	3	—
Blackstriped topminnow	1	0.2	—	—	41	3.5	20	—
Johnny darter	1	0.3	—	—	3	0.2	6	—
Brook silverside	5	0.8	4	—	6	0.3	8	—
Brook stickleback	1	0.2	—	—				
Warmouth	4	0.7	5	—	3	0.2	43	—
Blackside darter	1	0.2	—	—	1	—	2	—
White crappie	1	0.2	3	—	1	—	117	—
Iowa darter	—	—	—	—	1	—	1	—
Spotted sucker	—	—	—	—	1	—	382	0.3
Total	594		147,112		1,160		140,598	

Table 3. Total length (mm), weight (g), and condition (K) of sport and commercial species collected in 1985 from the Des Plaines River by all sampling methods.

	Age at capture											
	I				II				III			
Common name	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K
Largemouth bass	2	79	5	1.01	1	197	105	1.37	1	296	407	1.60
Bluegill	—	—	—	—	8	110	21	1.45	9	116	24	1.50
Green sunfish	8	67	6	1.50	8	99	20	1.86	—	—	—	—
Common carp	—	—	—	—	3	183	104	1.62	10	350	566	1.34
Yellow bass	1	87	5	0.76	4	154	44	1.18	—	—	—	—
Pumpkinseed	3	57	5	1.03	4	106	20	1.61	1	125	42	2.15
Black crappie	2	120	3	0.66	—	—	—	—	—	—	—	—
Yellow perch	2	89	7	0.99	—	—	—	—	—	—	—	—
Channel catfish	—	—	—	—	1	194	59	0.81	—	—	—	—
Yellow bullhead	—	—	—	—	1	181	78	1.32	2	223	147	—
Black bullhead	2	80	5	0.82	4	145	40	1.38	4	170	67	1.35
Northern pike	—	—	—	—	1	337	211	0.55	2	560	1,078	0.60

Table 3 (Continued). Total length (mm), weight (g), and condition (K) of sport and commercial species collected in 1985 from the Des Plaines River by all sampling methods.

	Age at capture											
	IV				V				VI			
Common name	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K
Largemouth bass	—	—	—	—	—	—	—	—	—	—	—	—
Bluegill	—	—	—	—	—	—	—	—	—	—	—	—
Green sunfish	—	—	—	—	—	—	—	—	—	—	—	—
Common carp	11	394	842	1.48	4	436	1,311	1.52	8	506	1,706	1.34
Yellow bass	—	—	—	—	1	205	130	1.51	—	—	—	—
Pumpkinseed	—	—	—	—	—	—	—	—	—	—	—	—
Black crappie	—	—	—	—	—	—	—	—	—	—	—	—
Yellow perch	—	—	—	—	—	—	—	—	—	—	—	—
Channel catfish	—	—	—	—	—	—	—	—	—	—	—	—
Yellow bullhead	—	—	—	—	—	—	—	—	—	—	—	—
Black bullhead	1	231	195	1.58	2	160	59	1.40	—	—	—	—
Northern pike	—	—	—	—	—	—	—	—	—	—	—	—

Table 3 (Continued). Total length (mm), weight (g), and condition (K) of sport and commercial species collected in 1985 from the Des Plaines River by all sampling methods.

	Age at capture											
	VII				VIII				IX			
Common name	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K	No.	Mean length (mm)	Mean weight (g)	K
Largemouth bass	—	—	—	—	—	—	—	—	—	—	—	—
Bluegill	—	—	—	—	—	—	—	—	—	—	—	—
Green sunfish	—	—	—	—	—	—	—	—	—	—	—	—
Common carp	4	538	1,948	1.22	1	605	3,147	1.42	1	612	3,345	1.46
Yellow bass	—	—	—	—	—	—	—	—	—	—	—	—
Pumpkinseed	—	—	—	—	—	—	—	—	—	—	—	—
Black crappie	—	—	—	—	—	—	—	—	—	—	—	—
Yellow perch	—	—	—	—	—	—	—	—	—	—	—	—
Channel catfish	—	—	—	—	1	625	3,260	1.34	—	—	—	—
Yellow bullhead	—	—	—	—	—	—	—	—	—	—	—	—
Black bullhead	—	—	—	—	—	—	—	—	—	—	—	—
Northern pike	—	—	—	—	—	—	—	—	—	—	—	—

Table 4. Catch of common carp per unit effort in 1986.

	Carp		
Date	Number	Total Weight (kg)	Mean Weight (kg)
9/8	136	191.69	1.41
9/9	153	215.89	1.41
9/10	65	70.47	1.08
9/11	30	37.08	1.03
Total	384	515.13	
Mean weight			1.34

Table 5. Fish species found in the upper Des Plaines River watershed (from Wisconsin-Illinois border to confluence of Salt Creek — approximately 28 km).

Common name	Scientific name	Family	1967[2]	1976[3]
Central mudminnow	*Umbra limi*	Umbridae	+	+
Northern pike	*Esox lucius*	Esocidae	+	+
Grass pickerel	*E. americanus*	"	+	+
Goldfish	*Carassius auratus*	Cyprinidae	+	+
Common carp	*Cyprinus carpio*	"	+	+
Hornyhead chub	*Nocomis biguttatus*	"	–	+
Golden shiner	*Notemigonus crysoleucas*	"	+	+
Emerald shiner	*Notropis atherinoides*	"	–	+
Common shiner	*N. cornutus*	–	–	+
Blackchin shiner	*N. heterolepis*	"	+	–
Bigmouth shiner	*N. dorsalis*	"	+	+
Rosyface shiner	*N. rubellus*	"	–	+
Spotfin shiner	*N. spilopterus*	"	+	+
Sand shiner	*N. stramineus*	"	+	+
Redfin shiner	*N. umbratilis*	"	+	+
Bluntnose minnow	*Pimephales notatus*	"	+	+
Fathead minnow	*P. promelas*	"	–	+
Creek chub	*Semotilus atromaculatus*	"	–	+
Common carp X goldfish[1]	—	"	+	+
White sucker	*Catostomus commersoni*	Catostomidae	+	+
Golden redhorse	*Moxostoma erythrurum*	"	–	+
Black bullhead	*Ictalurus melas*	Ictaluridae	+	+
Yellow bullhead	*I. natalis*	"	+	+
Channel catfish	*I. punctatus*	"	–	+
Stonecat	*Noturus flavus*	"	+	+
Tadpole madtom	*N. gyrinus*	"	+	+
Blackstriped topminnow	*Fundulus notatus*	Cyprinodontidae	+	+
Brook stickleback	*Culaea inconstans*	Gasterosteidae	+	+
Yellow bass	*Morone mississippiensis*	Percichthyidae	–	+
Rock bass	*Amboplites rupestris*	Centrarchidae	–	+

Green sunfish	*Lepomis cyanellus*	"	+	+
Pumpkinseed	*L. gibbosus*	"	+	+
Warmouth	*L. gulosus*	"	–	+
Bluegill	*L. macrochirus*	"	+	+
Smallmouth bass	*Micropterus dolomieui*	"	–	+
Largemouth bass	*M. salmoides*	"	+	+
White crappie	*Pomoxis annularis*	"	+	+
Black crappie	*P. nigromaculatus*	"	+	+
Johnny darter	*Etheostoma nigrum*	Percidae	+	+
Banded darter	*E. zonale*	"	–	+
Blackside darter	*Percina maculata*	"	–	+
Yellow perch	*Perca flavescens*	"	+	+
Pirate perch	*Aphredoderus sayanus*	Aphredoderidae	+	+

[1]This is a hybrid, not a species.
[2]Muench (1968).
[3]Brigham et al. (1978).

Table 6. Fish species not found in the upper Des Plaines watershed in 1976 by Brigham et al. (1978), but known historically to have been present based on records of the Illinois Natural History Survey.

Common name	Scientific name	Family
Bowfin[1]	*Amia calva*	Amiidae
Grass pickerel[2]	*Esox americanus*	Esocidae
Central Stoneroller	*Campostoma anomalum*	Cyprinidae
Ironcolor shiner	*Notropis chalybaeus*	"
Striped shiner	*N. chrysocephalus*	"
Blackchin shiner[1]	*N. heterodon*	"
Blacknose shiner	*N. heterolepis*	"
Mimic shiner[1]	*N. volucellus*	"
Blacknose dace	*Rhinichthys atratulus*	"
River carpsucker	*Carpiodes carpio*	Catostomidae
Creek chubsucker	*Erimyzon oblongus*	"
Lake chubsucker[1]	*E. sucetta*	"
Northern hogsucker	*Hypentelium nigricans*	"
Brown bullhead	*Ictalurus nebulosus*	Ictaluridae
Pirate perch	*Aphredoderus sayanus*	Aphredoderidae
Banded killifish	*Fundulus diaphanus*	Cyprinodontidae
Starhead topminnow	*F. notti*	"
Redear	*Lepomis microlophus*	Centrarchidae
Iowa darter[1,3]	*Etheostoma exile*	Percidae
Least darter	*E. microperca*	"

[1]These five species were found in 1979-1980 in the upper Des Plaines River in Kenosha County, Wisconsin, by Southern (1980).
[2]Species collected in 1985.
[3]Species collected in 1986.

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ZINC METHIONINE SUPPLEMENTATION FOR DAIRY COWS

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ABSTRACT

Thirty-six Holstein cows were used to determine the effects of adding zinc methionine (Zinpro 40) on milk yield, milk composition, somatic cell count, hoof growth, hoof wear, and hoof quality. Cows included in this study were paired based upon milk production, stage of lactation, and age. Within each pair, cows were randomly allotted to one of two groups, trt. or control. The trt. group was individually fed 200 mg of zinc methionine/hd/d. The trial ran for 1 year. Average milk yields were 26.9 and 27.1 kg/d for control and zinc methionine, respectively which were not statistically different. Milk fat and milk protein percentages were not affected by treatment. Serum Vit A increased slightly during the trial for both groups; however, the increase was greater for the methionine. Pre, mid, and post trial values of Vit A for the zinc methionine group were 38.5, 39.8, and 44.8 μg/dl respectively. Likewise, the pre, mid, and post trial values of Vit A for the control group were 35.7, 37.1, and 41.2 μg/dl. Serum beta carotene values showed greater fluctuation: 60.5, 133.7, and 52.3 μg/dl for zinc methionine and 56.7, 128.3, and 49.4 μg/dl for control. Somatic cell counts for the zinc methionine cows were 228,000 compared to 243,000 for controls. No change in plasma zinc was noted between groups. Hoof growth and wear measurements were similar for both groups; however, visual hoof scores (texture, heel cracks, interdigital dermatitis and hoof rot) showed improvement with zinc methionine.

INTRODUCTION

Zinc is an essential trace mineral required in ruminants for normal growth, reproduction and numerous biochemical processes. The reservoir of zinc in the animal's body is limited; therefore, zinc must be provided in the daily diet. Blood plasma is the immediate reservoir and small amounts of zinc are stored in the liver, kidney, pancreas, bone, muscle, skin and hair.[8] The blood reservoir is rapidly depleted whenever an animal becomes sick or stressed because zinc is employed as part of the anti-inflammatory reaction of the body. During the inflammatory reaction there is a significant drop in blood plasma zinc.[7] If the animal is sick or stressed for several days, the result is a negative zinc balance.

There is a constant requirement for zinc in enzyme reactions at the tissue and cellular levels. Zinc is needed for protein metabolism especially for the synthesis of RNA (Ribonucleic Acid) and DNA (Deoxyribonucleic Acid).[8] Zinc is usually supplemented to ruminants in the form of zinc oxide; however, this form of zinc may not always be well utilized by the animal. Zinc methionine is more bioavailable to the animal because it is not degraded by rumen organisms and thus is available for direct absorption[6]. Zinc methionine is one ion of zinc bound to one molecule of the amino acid methionine.

Kincaid and Hodgson[7] and Aguilar et al.[1] found increases in milk yield and a lower somatic cell count when zinc methionine was fed to lactating cows. On the other hand, Wealsby[9] found no significant differences in milk yield and somatic cell counts but did indicate an improvement in hoof scores with zinc methionine supplementation. The objectives of this trial were to study the effect of adding zinc methionine on milk yield, milk composition, somatic cell count, hoof growth, hoof wear and hoof quality.

MATERIALS AND METHODS

Thirty-six Holstein cows from the Illinois State University dairy herd were used in this experiment. The cows were divided into two groups of 18 cows each. The cows were paired as closely as possible based upon milk production, stage of lactation and age. One animal of each pair was assigned randomly to one of the two groups, control or test.

Diet

Both groups received a diet consisting of alfalfa haylage, corn silage, and alfalfa hay (large round bales) fed ad libitum in addition to a concentrate mixture consisting of corn, oats, sodium bicarbonate, minerals and vitamins. The concentrate was fed via a dual computer feeder where the cows received the concentrate mixture during eight different feedings over a 24 h period. The other dual feeder contained soybean meal (Table 1). Both concentrate mixture and soybean meal were fed according to production.

In addition, the cows were fed 1 kg of concentrate mix once daily (morning milking) in the milking parlor. The test group concentrate included an additional .5% zinc methionine in order to ensure an intake of 200 mg of zinc methionine per head per day (Table 2). Feed samples were collected periodically throughout the experiment and analyzed for crude protein (CP), acid detergent fiber (ADF), calcium (Ca), phosphorus (P), and zinc (Zn) (Table 3).

Hoof Growth and Wear Measurements

Hoof growth and wear measurements were estimated according to the procedure of Hahn[5] and Clark[4]. A soldering iron was used to burn a mark on the hoof wall 1 cm below the periople line in the dorsal and lateral regions of front and rear right hooves. The burn mark was used as a reference point for determining hoof growth and wear. The distances from the periople line to mark A and from the mark to the distal edge of the wall B were designated as growth and wear, respectively (Figure 1). Hooves were measured at 6 mo intervals. Each time hooves were measured, new marks were burned 1 cm below the periople line. As shown in Figure 1, the distance between the periople line and the new mark was designated as C, the distance between old and new marks D, and the distance from the new mark to the distal edge of the hoof E. Monthly rates of growth and wear were calculated by the following formulas as outlined by Clark[4].

Monthly growth:
$[(C + D - A)/\text{days between measurements}] \times 30.4,$
Monthly wear:
$[(B - E + D)/\text{days between measurements}] \times 30.4.$

Hoof Hardness Measurements

Hoof hardness was determined by using a Rockwell metal hardness tester[2]. A section of the dorsal front and rear hooves was trimmed from the cow and hardness was measured 1 cm from the bottom of the toe and 1½ cm from the inside claw (Figure 2).

Hoof Quality Measurements

Hoof evaluation scores were made by a professional hoof trimmer at 6 mo intervals. A numerical score of 1-5 was given with 1 being perfect, 2 good, 3 fair, 4 poor and 5 severe. The hoof trimmer had no knowledge of which animals were in each group.

Blood Analysis

Blood samples were drawn via the jugular vein on all cows for 2 consecutive days prior to the start of the trial, at 6 mo into the trial and for 2 consecutive days at the completion of the trial. Samples for plasma were centrifuged at 2500 rpm for 7 min and the plasma drawn off and frozen for later analysis. The plasma was used for zinc analysis by Atomic Absorption Spectroscopy (AAS). Each sample was analyzed by AAS using the standard addition method of analysis.

Blood samples for serum were allowed to separate in collecting tubes and the serum was then drawn off and frozen for later analysis. The spectrophotometric method of vitamin A and beta carotene analysis was done according to the procedure outlined by Chew et al.[3]

Statistical Analysis

The effect of zinc methionine on factors reported in this study were analyzed by one-way ANOVA using ABSTAT (Anderson-Bell Statistics).

RESULTS AND DISCUSSION

Hoof Growth and Wear

Hoof growth rates are shown in Table 4. There was greater growth from

November through May which corresponded to periods of increasing photoperiod. This was similar to the results of Hahn[5] and Clark[4]. During the period of May through November there was more growth ($P < .02$) with zinc methionine in the dorsal region of the front hooves. Hoof growth in the dorsal region of the rear hooves was greater ($P < .09$) with zinc methionine.

No differences were found between treatment groups for hoof wear rates. Dorsal wear of front hooves tended to be numerically higher than lateral wear of front hooves; however, no trend could be seen between dorsal and lateral wear of rear hooves (Table 5). Clark[4] found no significant differences for wear rates between the dorsal and lateral regions for either front or rear hooves, although the trend was for the lateral region to wear faster than the dorsal region.

Hoof Hardness

Hoof hardness scores are shown in Table 6. A section of the dorsal hoof was trimmed on the underside to give a flat surface. Readings with Rockwell metal hardness tester were taken at the apex area which was 1 cm from the bottom of the hoof and 1½ cm from the inside claw. Although the measures were not significantly different, the trend was toward a harder hoof with zinc methionine.

Visual Hoof Scores

As shown in Table 7 the zinc methionine group showed a significant improvement in texture ($P < .01$), heel cracks ($P < .05$) and interdigital dermatitis ($P < .01$). No cases of hoof rot were observed during November through May; however, 7 cases showed up in the control group and 2 in the zinc methionine group between May and November. Wealsby[9] also found a general improvement on hoof scores with zinc methionine supplementation. Zinc methionine appears to be effective in maintaining epithelial integrity.

Blood Analysis

Zinc is necessary for adequate hepatic synthesis of retinal-binding protein which is the major transport protein carrying Vit. A from the liver to sites of activity in peripheral tissue. There was no significant difference in Vit. A levels, but they began approaching a level of significance toward the end of the trial (Table 8). Serum beta carotene levels showed more variation than Vit. A levels (Table 9), but this would be expected because there is no storage of beta carotene in the liver and some of the carotene in the feed may have been lost in storage.

Plasma zinc levels between groups were not significantly different (Table 10). This result is not unexpected because the quantity of zinc methionine fed was small (200 mg/hd/d) and plasma levels were normal.

Reproduction

Very little differences existed between treatments regarding services per conception and days open (Table 11). Services per conception averaged 1.7 for controls and 1.9 for zinc methionine, and days open were 101 and 106 respectively. First service conception was 42.9 percent for controls and 53.8 percent for zinc methionine.

Milk Yield

There were no significant differences in milk yield composition (Table 12). Control cows averaged 26.9 kg and those receiving zinc methionine averaged 27.1 kg. There was no difference in milk fat or milk protein. Somatic cell count was not

significantly different (zinc methionine cows averaged 228,000 while control cows averaged 243,000). Likewise, there was no difference in the incidence of mastitis between the groups.

CONCLUSIONS

Adding 200 mg/hd/d of Zn methionine showed an improvement in visual hoof score, i.e. texture, heel cracks and interdigital dermatitis. There was also a trend towards harder hooves and fewer cases of hoof rot. There was an increased dorsal hoof growth in front and rear hooves and a trend towards less wear on lateral rear hooves. A slight elevation in serum Vit A was seen but there was no effect on serum beta carotene or plasma zinc. Although the first service conception rate trended higher, there was no difference in services/conception and days open. Milk yield, milk composition, somatic cell count or cases of mastitis were unaffected by zinc methionine supplementation.

ACKNOWLEDGMENTS

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REFERENCES

[1] Aguilar, A.A., M. Kujawa, and J.D. Olson. 1988. Zinc-Methionine Supplementation in Lactating Dairy Cows. National Mastitis Council, Inc. 27th Annual Meeting, Reno, NE.
[2] Annual Book of ASTM Standards. 1973. Part 27 Designation D785-65, Philadelphia, PA.
[3] Chew, B.P., D.M. Holpuch, and J.V. O'Fallon. 1984. Vitamin A and B-Carotene in Bovine and Porcine Plasma, Liver, Corpora Lutea, and Follicular Fluid. J. Dairy Sci. 67:1316-1322.
[4] Clark, A.K. and A.H. Rakes. 1982. Effect of Methionine Hydroxy Analog Supplementation on Dairy Cattle Hoof Growth and Composition. J. Dairy Sci. 65:1493-1502.
[5] Hahn, M.V. 1979. Studies of genetic and environmental characteristics of hooves of dairy cattle. Ph.D. dissertation, North Carolina State University, Raleigh.
[6] Heinrichs, A.J. and H.R. Conrad. 1983. Rumen Solubility and Breakdown of Metal Protein Compounds. J. Dairy Sci. 66:Suppl. 1:4. (Abstr.)
[7] Kincaid, R.L., A.S. Hodgson, J.E. Riley, and S.D. Conrath. 1984. Supplementation of Diets for Lactating Cows with Zinc as Zinc Oxide and Zinc Methionine, J. Dairy Sci., 67:Suppl. 1:103. (Abstr.)
[8] Schugel, L.M. 1983. The Role of Zinc Methionine In The Preventive and Treatment Programs of Foot Problems In The Bovine. Fourth International Symposium Foot Problems of the Ruminant. Paris/Marsma-Alfort, France.
[9] Wealsby, W.J. 1985. The Influence of Zinpro 100 on the Incidence of Foot Lesions and Lameness in Dairy Cows. J. Bibby Agriculture Field Trials. Final Report.

Table 1. Ingredients of rations.

Item	(% of mix)
Computer feeder mix	
corn, ground shelled	71.6
oats, ground	23.9
$NaHCO_3$	1.8
Mineral and vitamins	1.8
Trace mineral salt	.9
Computer feeder soybean meal[a]	
Roughage	%
alfalfa haylage	40
alfalfa hay	10
corn silage	50

[a]fed according to milk production.

Table 2. Composition of parlor fed concentrate.

Ingredient	Control	Zn methionine[a]
	%	
Corn, ground shelled	80	80
Soybean meal (SBM), 44% crude protein	20	19.5
Zn methionine[b]	—	.5

[a]Calculated Zn content, .02%; by analysis .019%.
[b]Trade name Zinpro 40.

Table 3. Chemical analysis of diet components.[a]

	DM (%)	CP (%)	ADF (%)	Ca (%)	P (%)	Zn (%)
Concentrate						
Parlor						
Control	84.5	18.8	7.9	.08	.42	.0016
Zinc	84.5	17.8	9.8	.08	.42	.0190
Computer feeder	86.0	8.2	4.3	.32	.40	.0030
Soybean meal[b]	89.0	49.9	—	.33	.71	.0061
Roughage						
Alfalfa haylage	61.2	22.6	44.1	2.13	.31	.0025
Alfalfa hay	89.0	17.5	30.0	1.31	.21	.0024
Corn silage	46.7	9.8	27.3	.21	.20	.0021

[a]100% dry matter bases and calculated by analysis.
[b]book values.

Table 4. Hoof growth rates.

Position	Diet	11/20/86 - 5/29/87 (mm/mo)		5/29/87 - 11/30/87 (mm/mo)	
		$\bar{X}$	SD	$\bar{X}$	SD
DGFH	Z	5.41	1.09	4.47*	.65
	C	5.37	.85	3.95*	.58
LGFH	Z	5.88	1.90	4.46	.88
	C	5.45	.91	4.59	.75
DGRH	Z	5.62†	.82	4.63	.74
	C	5.14†	.94	4.64	.92
LGRH	Z	5.94	1.16	5.10	.58
	C	5.98	.97	4.74	1.11

*P<.02
†P<.09

Table 5. Hoof wear rates.

Position	Diet	11/20/86 - 5/29/87 (mm/mo)		5/29/87 - 11/30/87 (mm/mo)	
		$\bar{X}$	SD	$\bar{X}$	SD
DWFH	Z	3.82	.81	3.13	.99
	C	3.76	1.28	3.03	.71
LWFH	Z	2.74	1.01	2.67	.71
	C	2.24	1.38	2.88	.76
DWRH	Z	3.66	1.04	3.14	.87
	C	3.49	1.34	2.82	.82
LWRH	Z	2.78†	1.44	3.63	1.19
	C	3.68†	1.86	3.62	1.72

†P<.10

Table 6. Hoof Hardness Scores.

	11-28-86				5-29-87				11-30-87			
	RFH*		RRH**		RFH		RRH		RFH		RRH	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Control	40.3	14.9	37.2	14.1	41.3	11.1	38.1	14.2	42.5	13.9	36.4	11.9
Zn methionine	41.2	13.1	43.1	15.2	45.9	12.2	44.9	15.6	46.2	12.9	44.5	16.6

*Right Front Hoof.
**Right Rear Hoof.

Table 7. Hoof evaluation scores.

	11-28-86		5-29-87		11-30-87	
	Zinc	Control	Zinc	Control	Zinc	Control
	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
Texture	2.62	2.71	1.48	1.65	2.11	3.11**
Heel cracks	1.90	1.76	1.81	2.00	1.58	2.50*
Laminitis	2.81	2.86	1.14	1.18	1.65	2.44†
Ulcers	1.71	1.38	1.38	1.29	1.24	1.61
White Line Dis.	1.42	1.00	1.38	1.29	1.65	1.78
Interdig. Derm.	1.76	1.67	1.00	1.06	1.06	1.94**

**P<.01
*P<.05
†P<.10
Scoring: 1-5, 1 - perfect, 2 - good, 3 - fair, 4 - poor, 5 - severe.

Table 8. Serum Vit. A levels.

	Start of trial μg/dl		6 mos. μg/dl		End of trial μg/dl	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Control	35.7	5.9	37.1	7.5	40.3†	5.9
Zn methionine	38.5	12.4	39.8	12.0	44.6†	7.8

†P<.10

Table 9. Serum Beta carotene levels.

	Start of trial μg/dl		6 mos. μg/dl		End of trial μg/dl	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Control	58.0	17.1	128.6	40.2	48.3	15.4
Zn methionine	60.3	16.4	133.7	65.5	52.0	14.5

Table 10. Effect of zinc methionine on plasma levels.

	Start of trial μg/dl		End of trial μg/dl	
	$\bar{X}$	SD	$\bar{X}$	SD
Control	70.1	13.2	73.5	14.9
Zn methionine	71.9	12.7	76.4	11.7

Table 11. Services per conception, days open, and first service conception rates.

	Control		Zn methionine	
	$\bar{X}$	SD	$\bar{X}$	SD
Services per conception	1.7	.73	1.9	1.3
Days open	101	36	106	49
First service conception rate	42.9%		53.8%	

Table 12. Milk yield and composition.

	Control	Zn methionine
Somatic cell count	243,000±510,000	228,000±305,000
Milk yield (kg)	26.9	27.1
Milk protein (%)	3.1	3.0
Milk fat (%)	3.4	3.3

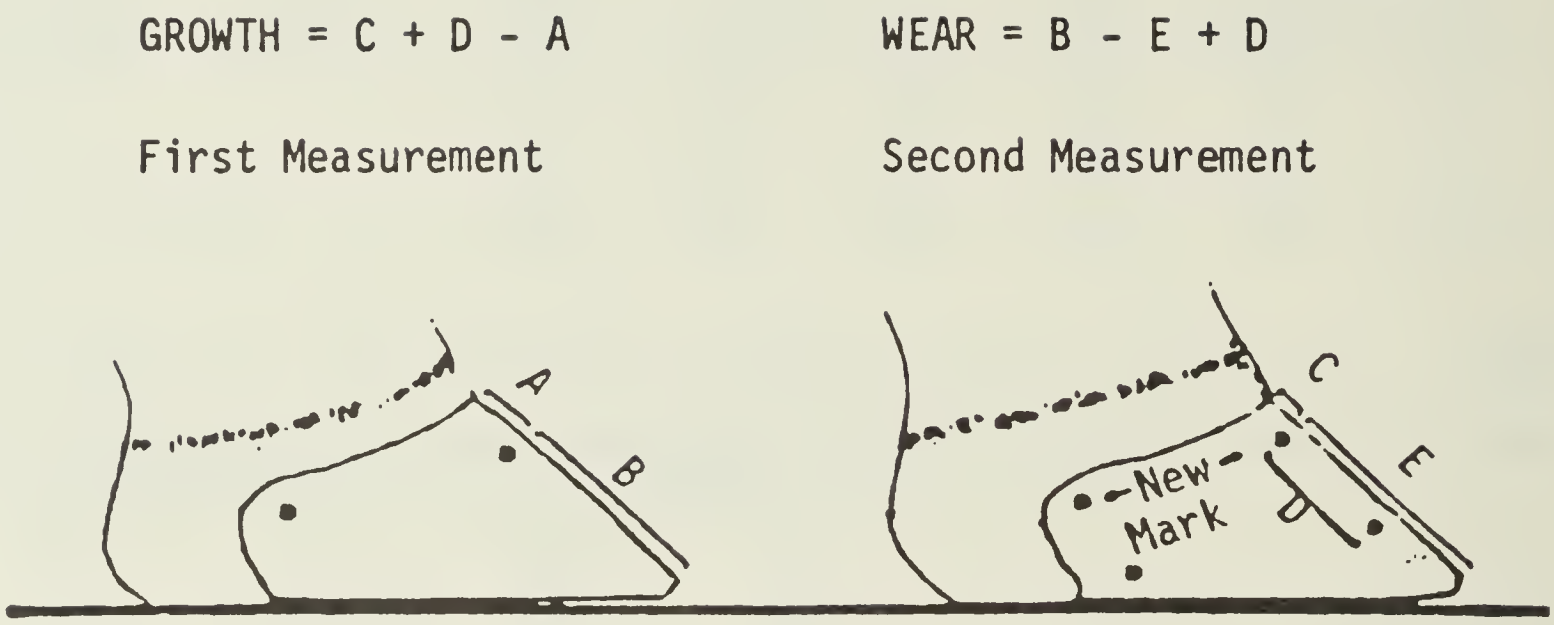

Figure 1. Measurements of hoof to estimate hoof growth and wear. (Clark, 1982)

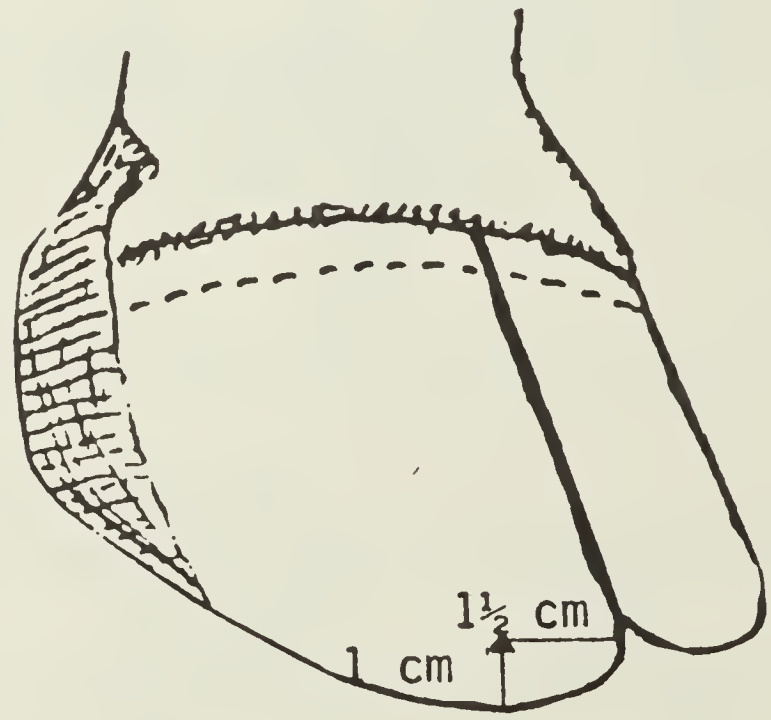

Figure 2. Location for measurements of hoof hardness estimates.

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THE TAXONOMY, ECOLOGY, AND DISTRIBUTION OF MARASMIUS (AGARICALES, TRICHOLOMATACEAE) IN ILLINOIS

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ABSTRACT

The genus *Marasmius* is described as it occurs in Illinois. A key to treated taxa is provided along with references to modern descriptions, habit and habitat, fruiting periods, county distributions, and diagnostic characters. Nineteen species of *Marasmius* are reported as occurring in Illinois. Of these, *Marasmius felix* and *M. strictipes* are reported as new Illinois state records. A macro- and micromorphological description is provided for the previously little known species *M. felix*. Numerous new county records are established for eight of the taxa. The results of this study indicate that many *Marasmius* species are more abundant in the deciduous forests of Illinois than previously recognized.

INTRODUCTION

Often overlooked by many field biologists and even some agaricologists, members of the genus *Marasmius* represent a significant portion of the central North American deciduous forest mycota. In temperate regions these fungi are primarily saprophytes on dicotyledonous plant debris (Gilliam, 1976), although two species—*Marasmius graminum* (Lib.) Berk., and *Marasmius scorodonius* (Fr.) Fr. are known to be facultative parasites of some grasses (e.g., wheat) and sedges—

(Tehon, 1924a; Young, 1925; and Boewe, 1937). In Illinois, species of *Marasmius* are most abundant during the summer and fall, often occurring in great numbers.

Recent work on the marasmioid fungi of Illinois and adjacent Kentucky and Missouri, conducted by the senior author from 1983 to 1985 indicate a larger marasmioid flora than previously recognized (Doyle, 1985 and 1987). This work summarizes previous scattered reports of Marasmii from Illinois and establish new state and county records. Many species of this genus are relatively well known from other regions and have been adequately described (e.g., Singer, 1958 and 1964; Gilliam, 1975 and 1976; Singer, 1976; and Halling, 1983). Earlier monographic treatments on *Marasmius* in North America include Morgan (1905-1906) and Pennington (1915).

References to modern descriptions are provided for 18 of the 19 Marasmii included in this treatment. Diagnostic morphological and ecological characteristics are presented for all taxa. Lacking adequate published descriptions, *M. felix* is described both macro- and micromorphologically in this report. Taxa in other allied genera (i.e., *Collybia*, *Marasmiellus*, and *Mycena*) previously reported from Illinois as species of *Marasmius* are listed under excluded species. A key for rapid determination of the taxa is also included.

MATERIALS AND METHODS

Macromorphological data were obtained from both fresh and dried material. Descriptive terminology is that of Singer (1975). Color terminology is that of Ridgway (1912, cited as "R") and Maerz and Paul (1950, cited as "M&P").

Micromorphological data were compiled from dried material mounted in concentrated NH_4OH and Melzer's reagent as described by Singer (1942). Observations were made utilizing a Leitz microscope with a 1.3 n.a. oil immersion lens. All collections, unless otherwise noted, are deposited in the Mycological Collections, Southern Illinois University Herbarium, Southern Illinois University at Carbondale, Carbondale, Illinois (SIU). Herbarium designations are those of Holmgren and Keuken (1974). In many cases, voucher collections from previous reports apparently do not exist. County records followed by literature citations indicate collections and records that were not verified by the present authors.

Taxonomic Treatment

Marasmius Fries, Fl. Scan. 339. 1835, nom. cons., emend. Singer, Mycologia 50: 103. 1958.

Basidiomes marasmioid, collybioid, pleurotoid, or mycenoid, generally tough and reviving when moistened; lamellate or nearly so, hymenial cystidia usually present; epicutis hymeniform or composed of diverticulate or sometimes smooth hyphal elements; spore print white or rarely yellowish; spores hyaline, variously shaped, smooth, inamyloid; basidia usually 4-spored; stipe central to eccentric or lacking, often bristle-like or cartilaginous, insititious or with a basal mycelial disc; sterile stipes or black rhizomorphs often present; hyphae generally with clamp connections. Cosmopolitan (although predominantly tropical), primarily saprophytes (some parasites) occurring on both woody and herbacious plant material. For a more complete delimitation of *Marasmius* see Singer (1975 and 1976) and Gilliam (1976).

Key to the Genus *Marasmius* in Illinois

1. Basidiomes collybioid or pseudo-marasmioid; pileus typically 3 cm or greater in diameter 2
1. Basidiomes marasmioid, pileus typically less than 3 cm in diameter 6
   2. Occurring in lawns, pastures and meadows, often forming conspicuous fairy rings; hymenial cystidia absent ..... 12. *M. oreades*
   2. Occurring on deciduous or coniferous debris in woods; fairy rings mostly lacking; hymenial cystidia present 3
3. Pileus usually less than 4 cm in diameter 4
3. Pileus usually larger (up to 11 cm broad) 5
   4. Pileus white to yellowish-white ..... 5. *M. delectans*
   4. Pileus yellowish-brown to dark brown ..... 4. *M. cohaerens*
5. Pileus yellowish-buff with a reddish disk, often large (up to 11 cm broad) ..... 10. *M. nigrodiscus*
5. Pileus orange-yellow to yellow-buff, typically less than 7 cm broad ..... 18. *M. strictipes*
   6. Lamellae adnate to a free collar 7
   6. Lamellae adnate or adnexed directly to the stipe, free collar usually absent 10
7. Parasitic on stems and leaves of grasses and sedges; pileus orange ..... 8. *M. graminum*
7. Saprophytic on dicotyledonous or coniferous substrates 8
   8. Pileus reddish; stipe with long inamyloid hairs; very rare ..... 11. *M. olneii*
   8. Pileus otherwise; stipe black, long and wiry, glabrous 9
9. Stipe thin (less than 0.3 mm thick when fresh); on decaying hardwood leaves (especially *Quercus*) ..... 3. *M. capillaris*
9. Stipe thicker (greater than 0.3 mm thick; on decaying dicotyledonous wood ..... 15. *M. rotula*
   10. Mature pileus typically less than 7.5 mm broad 11
   10. Mature pileus typically greater than 10 mm broad 13
11. Pileus brown, plane in age; occurring on decaying *Quercus* leaves or conifer debris ..... 1. *M. androsaceous*
11. Pileus and substrate otherwise 12
   12. Occurring on dead *Platanus* petioles and primary veins; pileus white to pinkish-buff in age ..... 6. *M. felix*
   12. Occurring on dead *Fraxinus, Ulmus, Pyrus,* or *Populus* leaves; pileus brownish ..... 9. *M. minutus*
13. Pileus bright orange, sulcate-plicate; in troops on hardwood debris ..... 17. *M. siccus*
13. Pileus brownish, yellowish, pink, or deep orange (if orange, pileus not sulcate-plicate) 14
   14. Pileus pinkish, sulcate-plicate; solitary on hardwood debris ..... 13. *M. pulcherripes*
   14. Pileus not pinkish and not sulcate-plicate; usually not solitary 15
15. Pileus brownish yellow; stipe long and radicating ... 14. *M. pyrrhocephalus*
15. Pileus and stipe otherwise 16

16. Odor of crushed pileus garlic or onion-like; on conifer needles, bark of trees, or rarely parasitic on dicots ..... 16. *M. scorodonius*
16. Odor of crushed pileus not garlic or onion-like; substrate otherwise, never parasitic 17
17. Pileus orange, red, or reddish-orange; stipe and disk often with purplish tint; spores narrow (4 um or less wide) ..... 2. *M. bellipes*
17. Pileus orange or yellowish-brown; stipe and disk without purplish tint; spores wider than 4 um) 18
18. Pileus deep orange to reddish-orange; lamellae close; basal mycelium abundant ..... 19. *M. sullivantii*
18. Pileus yellowish-brown; lamellae distant; basal mycelium absent ..... 7. *M. glabellus*

Taxa

1. ***Marasmius androsaceus*** (L.) Fr. Epicr. Mycol., p. 385. 1838.

This species has been recently described by Gilliam (1976: 28).

HABIT AND HABITAT: Gregarious on decaying *Quercus* spp. leaves in mixed deciduous forest. July. Not common. Also see discussion below.

COUNTY DISTRIBUTION: Jackson Co.: (Bankson and Gilman, 1963); Doyle X-7-84/2.

DISCUSSION: The brownish pileus and distinctive lamellar diverticulate cells characterize this species. In adjacent regions, and elsewhere, it generally occurs on coniferous leaves, cones and debris. As indicated above, it is also occasionally found on *Quercus* leaves.

2. ***Marasmius bellipes*** Morg. J. Mycol. 11: 207. 1905.

For a recent description see Gilliam (1976: 96).

HABIT AND HABITAT: Gregarious on old leaves in deciduous woods. June-September (Gilliam, 1976). Rare.

COUNTY DISTRIBUTION: County not recorded (northern Illinois and vicinity): (Routien, 1940).

DISCUSSION: This species is similar in many respects to *M. glabellus, M. borealis,* and *M. pulcherripes.* It is characterized by a convex-depressed, distantly striate pileus with a purplish disk; broad, distant lamellae, and a purplish stipe. For additional differences between these taxa see Gilliam (1976).

3. ***Marasmius capillaris*** Morg. J. Cincinnati Soc. Nat. Hist. 6: 194. 1883.

For a recent description see Gilliam (1976: 117).

HABIT AND HABITAT: Scattered to gregarious on decaying hardwood leaves, especially *Quercus* spp. in mesic woods. June-October. Common.

COUNTY DISTRIBUTION: Cook Co.: (Routien, 1936). Jackson Co.: Doyle X-7-84/3; Gormy 1. Ogle Co.: Doyle IX-29-84/4. Williamson Co.: Doyle VI-10-85/2, X-13-84/1, X-28-84/4, and VI-10-85/2. County not recorded (northern Illinois and vicinity): (Routien, 1940).

DISCUSSION: This species is easily recognized by its occurrence on decaying hardwood leaves, the presence of a long, thin and wiry black stipe surrounded by an apical collar, and a white to buff pileus which is usually umbilicate. It is especially common in the oak forests of the southern Illinois region during the summer and early fall.

4. ***Marasmius cohaerens*** (Pers.) Cke. & Quel.
Clavis Hymen. p. 153. 1878, var. ***cohaerens*** Gilliam Mycotaxon 4: 58. 1976.

For a description see Gilliam, *l.c.*

HABIT AND HABITAT: Gregarious on forest litter in deciduous and coniferous woods (Gilliam, 1976). July and August (Moffatt, 1909). Apparently not common.

COUNTY DISTRIBUTION: County not recorded (northern Illinois and vicinity): [reported as *Marasmius calopus* Pres.] (Moffatt, 1909).

DISCUSSION: Gilliam (1976) recognized two varieties—*M. cohaerens* var. *cohaerens* and *M. cohaerens* var. *lachnophyllus*. *M. cohaerens s. lat.* is a rather large marasmioid agaric having a brownish pileus up to 4 cm broad with conspicuous hymenial setae.

5. ***Marasmius delectans*** Morg. J. Mycol. 11: 206. 1905.

For a recent description see Gilliam (1976: 54).

HABIT AND HABITAT: Scattered to gregarious on decaying hardwood leaf litter (especially *Quercus* spp.) in mesic woods. June-November. Common.

COUNTY DISTRIBUTION: Jackson Co.: Doyle X-22-84/0, X-13-84/5, X-13-84/13, and IX-26-84/1; Sundberg 2475, and 4368. McDonough Co.: (Johnson, 1952). McLean Co.: (Cooke, 1969). Ogle Co.: Doyle IX-29-84/0. Union Co.: West *s.n.* (22 July, 1970). County not recorded: (Routien, 1940; Gilliam, 1976).

DISCUSSION: This taxon is characterized by a yellowish-white pileus up to 4 cm broad and abundant, conspicuous hymenial setae. It is quite common in mixed, mesic, deciduous forest during the late summer and early fall in the southern Illinois region.

6. ***Marasmius felix*** Morg. J. Mycol. 12: 2. 1906.

PILEUS 1.5-7 mm broad, semihemispheric at first, becoming convex, later broadly convex to nearly plane, occasionally upturned in age, centrally depressed in some specimens (forming a shallow umbo), sulcate or nearly so upon drying, the sulcae extending from the disk to the margin, rugulose, especially in dried specimens; margin entire, minutely crenate to eroded in age. CUTICLE dry, glabrous (atomate at 10X); concolorous or darkest at disk, white at first becoming light "orange white" (M&P 5A2), "greyish orange" (M&P 6B5-6B4), "salmon-buff", "light ochraceous-salmon", or "pinkish cinnamon" (R) upon drying. TRAMA thin (less than 1 mm thick), translucent white. ODOR mild (earthy) to absent. TASTE absent. LAMELLAE adnate to adnexed; pseudocollarium present, adnate to stipe (formed by both lamellae and pileus trama), lamellae broad, off-white to "light salmon buff" (R), margin entire; lamellulae present, some intervenose. STIPE 1-8.5 cm long, thin (less than 0.25 mm thick), equal, straight to wiry, occasionally

branched, cartilaginous, hollow, opaque, sparsely hairy to nearly glabrous at apex, black to blackish-brown at base, fading lighter upwards to "chaetura drab" (R), "taupe brown" (R), apex pale "ochraceous-salmon" (R), to off-white, inserted, insititious. STERILE STIPES, BASAL MYCELIUM, and RHIZOMORPHS absent.

SPORES white in mass, 8-8.5 X 2.8-3.5 um, fusoid, smooth, hyaline, inamyloid. BASIDIA 22-30 X 4-9 um, clavate, 4-spored, thin-walled, hyaline, with basal clamp. BASIDIOLES fusoid with narrow apices. HYMENIAL CYSTIDIA 34-45 X 4-10 um, ampullaceous, thin-walled, hyaline. TRAMAL HYPHAE hyaline, with clamp connections, inamyloid. For a description of the epicutis and stipe surface see Gilliam (1976).

HABIT AND HABITAT: Gregarious on decaying *Platanus occidentalis* petioles and major veins in mesic woods. July-December. Common.

COUNTY DISTRIBUTION: Jackson Co.: Doyle XII-4-84/1. Johnson Co.: Doyle XII-2-84/4. Randolph Co.: Doyle XII-14-84/1. Union Co.: Doyle XII-17-84/8. Williamson Co.: Doyle X-31-84/1.

DISCUSSION: This taxon is easily recognized by its occurrence on *Platanus* petioles, small size, and whitish pileus becoming pinkish in age. Previously considered very rare, this species is extremely common on the previous year's *Platanus* leaf litter, often buried by newly dropped leaves. Due to the insulative quality of the newly fallen leaves above, the fungus is able to produce basidiocarps during periods of sub-zero C. weather. It is notable that *M. felix* is pigmented in age, an anomalous character for section *Epiphylli*, of which it is a member. Additionally, some specimens have distinctly branched stipes, a character rarely observed in extratropical agarics.

7. ***Marasmius glabellus*** Pk. Bull. Buffalo Soc. Nat. Sci. 1:58. 1873 (1874).

For a description see Gilliam (1976: 91).

HABIT AND HABITAT: Gregarious on decaying leaves in deciduous woods (Gilliam, 1976). August-September (Graham, 1944). Not common (Graham, 1944).

COUNTY DISTRIBUTION: Lake Co.: (Routien, 1936). McLean Co.: (Cooke, 1969). County not reported: (Routien, 1940; Graham, 1944).

DISCUSSION: This taxon is characterized by its yellowish-brown pileus up to 1.5 cm broad, distantly spaced lamellae, and conspicuous shallow sulcae.

8. ***Marasmius graminum*** (Lib.) Berk. & Br. Outl. Brit. Fungol. 222. 1865, var. ***graminum*** Sing. Flora Neotropica Monog. 17: 152. 1976.

For a description see Singer, *l.c.* and Gilliam (1976: 112).

HABIT AND HABITAT: Scattered to gregarious on live and dying stems and leaves of grasses, and occasionally sedges. June-September. Not common.

COUNTY DISTRIBUTION: Madison Co.: [reported as *Marasmius tritici* Young] (Young, 1925). Alexander, Edgar, Knox, and Wabash Counties: (Boewe, 1937). Madison Co.: (Gilliam, 1976). Lake Co.: Singer N 4670 (F) (Singer, 1976). Williamson Co.: Doyle VI-13-85/1 and VI-18-85/1. County not recorded: (Roberts, 1943).

DISCUSSION: This species is characterized by its small size, orange pileus, and occurrence on dead and dying stems of grasses. *Marasmius graminum s. lat.* has been reported by various authors (e.g., Young, 1925; Boewe, 1937) as a parasite of some cereal grains (e.g., wheat) in Illinois.

9. ***Marasmius minutus*** Pk. Annual Rep. New York State Mus. 27: 97. 1873 (1875).

For a recent description see Gilliam (1976: 108).

HABIT AND HABITAT: Gregarious on decaying *Fraxinus, Ulmus, Pyrus,* or *Populus* leaves and twigs (Gilliam, 1976).

COUNTY DISTRIBUTION: Clay and Marion Counties: [reported as *Marasmius pyrinus* Ellis] (Boewe, 1937).

DISCUSSION: This species superficially resembles *M. graminum,* but differs by not possessing a free collar and occurs primarily on *Fraxinus* leaves. (*Marasmius minutus* is also known occasionally to parasitize living leaves of *Pyrus*) (Boewe, 1937).

10. ***Marasmius nigrodiscus*** (Pk.) Halling. Brittonia 35: 323. 1983.

For a description see Halling, *l.c.*

HABIT AND HABITAT: Solitary to gregarious, or caespitose on decaying forest litter in deciduous and coniferous woods, and occasionally lawns (Halling, 1983). Fruiting period not known.

COUNTY DISTRIBUTION: Union Co.: Halling 3401 (FH) (Halling, 1983).

DISCUSSION: This taxon is characterized by its relatively large (up to 11 cm broad) yellowish-buff pileus and reddish-brown disk, conspicuous hymenial cystidia, and caulocystidia (Halling, 1983).

11. ***Marasmius olneii*** Berk. & Curt. Ann. Mag. Nat. Hist. III, 4: 294. 1859.

For descriptions see Gilliam (1976: 116), Morgan (1905: 235), and Pennington (1915: 280).

HABIT AND HABITAT: Gregarious on hardwood twigs in beech-maple woods. September. Rare (Graham, 1944).

COUNTY DISTRIBUTION: McDonough Co.: (Johnson, 1952). County not recorded: (Graham, 1944).

DISCUSSION: This apparently is a small reddish-colored species possessing a free apical collar. This taxon is unfortunately poorly known (Gilliam, 1976). It has been reported from Illinois by Johnson (1952) and Graham (1944) as *M. olneyi* Berk. & Curt.

12. ***Marasmius oreades*** (Bolt.: Fr.) Fr. Epicr. Mycol., p. 375. 1838.

For a recent description see Gilliam (1976: 43).

HABIT AND HABITAT: Scattered to gregarious in lawns, pastures, and meadows. August-October. Common.

COUNTY DISTRIBUTION: Cook Co.: (Graham, 1927). Jackson Co.: Doyle X-26-

84/1. Monroe Co.: Jacobitz *s.n.* (*n.d.*). Union Co.: Sundberg 3011. Woodford Co.: Sundberg 3018. County not recorded (northern Illinois and vicinity): (Moffatt, 1909; Graham, 1933; Eifert, 1952).

DISCUSSION: This species is easily distinguished by its occurrence on lawns, moderately large yellowish-tan pileus (up to 4 cm broad), and absence of hymenial cystidia. Often forming conspicuous fairy rings, this species is a popular edible mushroom. *Marasmius oreades* appears to be less common in Illinois in relation to other temperate regions of North America.

13. ***Marasmius pulcherripes*** Pk. Annual Rep. New York State Mus. 24: 77. 1871.

For a recent description see Gilliam (1976: 99).

HABIT AND HABITAT: Solitary on decaying leaf litter in mesic deciduous woods. August-October. Not common.

COUNTY DISTRIBUTION: Jackson Co.: Burton 63. Williamson Co.: Doyle X-13-84/3.

DISCUSSION: This species is similar in many respects to *M. siccus*, but differs in having a pinkish pileus, a somewhat more fragile stipe, and is generally solitary. For additional comparisons of the two species see Gilliam (1976).

14. ***Marasmius pyrrhocephalus*** Berk. London J. Bot. 6: 316. 1847.

For a recent description see Gilliam (1975: 36).

HABIT AND HABITAT: Scattered to gregarious on decaying *Quercus* leaf litter in mesic, mixed deciduous forests. September-November. Common.

COUNTY DISTRIBUTION: DuPage Co.: [reported as *Marasmius longipes* Peck] (Moffatt, 1909). Jackson Co.: Doyle IX-13-84/6 and IX-13-84/9. Ogle Co.: Doyle IX-29-84/17, IX-29-84/0, and IX-29-84/M. Williamson Co.: Doyle XI-24-84/3.

DISCUSSION: This species is characterized by a typically small (usually around 1 cm broad) broadly convex to nearly plane brownish-yellow pileus; a tough, radicating, long and relatively thin pubescent stipe (up to 10 cm long) which is often brownish below and yellowish above; and lacking lamellar diverticulate cells.

15. ***Marasmius rotula*** (Scop.: Fr.) Fr. Epicr. Mycol., p. 385. 1838.

For a recent description see Gilliam (1976: 122).

HABIT AND HABITAT: Gregarious on rotting dicotyledonous wood in mesic deciduous woods. June-November. Common.

COUNTY DISTRIBUTION: Cook Co.: (Routien, 1936). Jackson Co.: (Bankson and Gilman, 1963); Burton 164: Connor 5; Nickles *s.n.* (6-1-74); Sundberg 2208 and 2295; West 404. Johnson Co.: Sundberg 3304. McDonough Co.: (Johnson, 1952). Randolph Co.: West 306. Williamson Co.: Doyle VI-10-85/1. County not recorded: (Gilliam, 1976); (northern Illinois and vicinity): (Moffatt, 1909; Graham, 1933).

DISCUSSION: *Marasmius rotula* is quite similar both macro- and micromorphologically to *M. capillaris*. *Marasmius rotula* generally occurs on rotting wood, and has a somewhat shorter and thicker stipe. For additional comparisons see Gilliam (1976).

16. ***Marasmius scorodonius*** (Fr.) Fr. Epicr. Mycol., p. 379. 1838.

For a recent description see Gilliam (1975: 29).

HABIT AND HABITAT: Scattered to gregarious on conifer needles in woods; occasionally parasitic on grasses in woods or fields; and the bark of living trees. June-September (Graham, 1944). Not common.

COUNTY DISTRIBUTION: Cook Co.: Shaffer 787 (MICH) (Gilliam, 1975). Jackson Co.: (French, 1907). Madison Co.: (Tehon, 1924b). County not recorded (northern Illinois and vicinity): (Routien, 1940).

DISCUSSION: This species is characterized by having a distinct garlic odor when the pileus is crushed and spores 6-10 um long. *Marasmius scorodonius* has an exceptionally wide range of substrates (Gilliam, 1975). This species has been reported as a parasite of some grasses, including wheat (Tehon, 1924b).

17. ***Marasmius siccus*** (Schw.) Fr. Epicr. Mycol., p. 382. 1838.

For a recent description see Gilliam (1976: 85).

HABIT AND HABITAT: Scattered to gregarious (often in troops) on decaying leaf litter in mesic deciduous woods. June-October. Common.

COUNTY DISTRIBUTION: Cook Co.: (Moffatt, 1909; Routien, 1936). Jackson Co.: Doyle VIII-12-84/1 and IX-13-84/2; Jacobs 23; Heil 55 and 61; Smith 10. Lake Co.: (Routien, 1936). McDonough Co.: (Johnson, 1952). McLean Co.: (Cooke, 1969). Randolph Co.: West 303. Williamson Co.: Doyle X-13-84/9 and X-7-84/1. County not recorded: (Gilliam, 1976); (northern Illinois and vicinity): (Graham, 1933).

DISCUSSION: This species is easily recognized by its bright orange, sulcate-plicate campanulate pileus. *Marasmius siccus* often occurs in great numbers on the forest floor after moderate to heavy rains. It is one of the most common and conspicuous members of Illinois deciduous forest agaric mycota.

18. ***Marasmius strictipes*** (Pk.) Sing. Ann. Mycol. 41: 130. 1943.

For a description see Gilliam (1976: 50).

HABIT AND HABITAT: Scattered to gregarious on decaying leaf litter in mesic deciduous woods. September. Not common.

COUNTY DISTRIBUTION: Jackson Co.: Sundberg IX-25-84/1.

DISCUSSION: This species is characterized by an orange-yellow to yellowish-buff pileus up to 6.5 cm broad, closely spaced lamellae, and abundant caulocystidia.

19. ***Marasmius sullivantii*** Mont. Syll. Crypt., p. 143. 1856.

For a recent description see Gilliam (1976: 70).

HABIT AND HABITAT: Gregarious on hardwood leaf litter in mesic woods. June-Sept. Not common.

COUNTY DISTRIBUTION: Jackson Co.: Orr *s.n.* (5-12-74). County not recorded: Shaffer 842 (MICH) (Gilliam, 1976).

DISCUSSION: This species is distinguished by a deep orange to brownish plano-convex pileus up to 3 cm broad. Apparently, Morgan (1905) interpreted *M. sullivantii* to be a saffron red agaric, growing among mosses. For synonomy, and a discussion of *M. sullivantii,* see Gilliam (1976).

Excluded Taxa

1. *Marasmius dichrous* Berk. & Curt.
Reported from northern Illinois and vicinity (Moffatt, 1909).
= **Collybia dichrous** (Berk. & Curt.) Gilliam

2. *Marasmius erythropus* (Pers.: Fr.) Fr.
Reported by Graham (1944), County not reported.
= **Collybia erythropus** (Pers.: Fr.) Lange

3. *Marasmius foetidus* Sow.: Fr.
Reported from northern Illinois and vicinity (Roberts, 1943).
= **Micromphale foetidum** (Sow.: Fr.) Sing.

4. *Marasmius magnisporus* Murr.
Reported from northern Illinois and vicinity (Routien, 1940), and from Cook Co. (Routien, 1936).
= **Marasmiellus candidus** (Fr.) Sing.

5. *Marasmius nigripes* Schw.
Reported from northern Illinois and vicinity (Moffatt, 1909).
= **Marasmiellus nigripes** (Schw.) Sing.

6. *Marasmius nucicola* McDougall
Reported from Champaign Co. (McDougall, 1924).
= **Mycena luteopallens** (Pk.) Sacc.

7. *Marasmius ramealis* Fr.
Reported from northern Illinois and vicinity (Routien, 1940), and from Cook Co. (Routien, 1936).
= **Marasmiellus ramealis** (Fr.) Sing.

8. *Marasmius semihiritipes* Pk.
Reported from Cook Co. (Routien, 1936), McDonough Co. (Johnson, 1952), and from northern Illinois and vicinity (Routien, 1940).
= **Collybia spongiosa** (Berk. & Curt.) Sing.

9. *Marasmius subnudus* (Ell.) Pk.
Reported from Lake Co. (Routien, 1936).
= **Collybia subnuda** (Ell.: Pk.) Gilliam

10. *Marasmius urens* (Fr.) Fr.
Reported from northern Illinois and vicinity (Moffatt, 1909).
= **Collybia subnuda** (Ell.: Pk.) Gilliam

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LITERATURE CITED

Bankson, M.M. and J.C. Gilman. 1963. A preliminary checklist of fleshy fungi from Jackson and Union Counties, Illinois. Trans. Illinois Acad. Sci. 56: 98-100.

Boewe, G.H. 1937. Tiny Toadstools on crop plants in Illinois. Trans. Illinois Acad. Sci. 30: 103-104.

Cooke, W.B. 1969. The Illinois foray. Mycologia 61: 817-822.

Doyle, M.F. 1985. A floristic survey of fleshy fungi from the Hawaiian Islands with notes on common marasmioid fungi from southern Illinois. M.Sc. Thesis. Southern Illinois University, Carbondale, 130 pp.

Doyle, M.F. 1987. The genus *Crinipellis* (Basidiomycetes, Agaricales, Tricholomataceae) in Illinois. Nova Hedwigia 44: 281-289.

Eifert, V.S. 1952. Exploring for mushrooms. Illinois State Museum; the story of Illinois 3.

French, G.H. 1907. A study in macro-fungi, mushrooms. Normal School Bull. 1 (4): 1-14. (Published by Southern Illinois Normal School, Carbondale).

Gilliam, M.S. 1975. *Marasmius* section *Chordales* in the northeastern United States and adjacent Canada. Contr. Univ. Michigan Herb. 11: 25-40.

Gilliam, M.S. 1976. The genus *Marasmius* in the northeastern United States and adjacent Canada. Mycotaxon 4: 1-144.

Graham, V.O. 1927. The ecology of fungi in the Chicago region. Bot. Gaz. 83: 267.

Graham, V.O. 1933. Mushrooms of the Chicago region. Program Activities Chicago Acad. Sci. 4: 42-63.

Graham, V.O. 1944. Mushrooms of the Great Lakes region. Chicago Acad. Sci. 390 pp., 49 pl.

Halling, R.E. 1983. A synopsis of *Marasmius* section *Globulares* (Tricholomataceae) in the United States. Brittonia 35: 317-326.

Holmgren, P.K. and W. Keuken. 1974. Index herbariorum, Part 1. The herbaria of the world. 6th ed. Regnum Veg. 92: i-vii, 1-397.

Johnson, M.M. 1952. Checklist of fleshy fungi collected in west-central Illinois. Trans. Illinois State Acad. Sci. 45: 27-30.

Maerz, A. and M.R. Paul. 1950. A dictionary of color. 2nd ed. McGraw-Hill, New York. 208 pp., pl. 1-56.

McDougall, W.B. 1924. A new mushroom. Trans. Illinois Acad. Sci. 17: 84.

Moffatt, W.S. 1909. The higher fungi of the Chicago region. I. The Hymenomycetes. Bull. Nat. Hist. Surv. Chicago Acad. Sci. 7: 1-24.

Morgan, A.P. 1905-1906. North American species of *Marasmius*. J. Mycol. 11: 201-212, 233-247; 12: 1-9, 159-162.

Pennington, L.H. 1915. North American species of *Marasmius*. N. Amer. Flora 9: 250-286.

Ridgway, R. 1912. Color standards and color nomenclature. Published by the author, Washington, D.C., 43 pp.

Roberts, J.M. 1943. Additions to the mycological flora of the Chicago region. Pap. Michigan Acad. Sci. 29: 51-53.

Routien, J.B. 1936. Mushrooms of Evanston and vicinity. M.A. Thesis. Northwestern Illinois University, Evanston. 106 pp., 7 pl.

Routien, J.B. 1940. New Agaricaceae of the Chicago region. Proc. Indiana Acad. Sci. 49: 84-85.

Singer, R. 1942. A monographic study of the genera *Crinipellis* and *Chaetocalathus*. Lilloa 8: 441-534.

Singer, R. 1958. Studies towards a monograph of the South American species of *Marasmius*. Sydowia 12: 54-145.

Singer, R. 1964. Monographic studies on South American Basidiomycetes, especially those of the East Slope of the Andes and Brazil, 2. The genus *Marasmius* in South America. Sydowia 18: 106-358.

Singer, R. 1975. The Agaricales in modern taxonomy. 3rd ed. J. Cramer, Vaduz. 912 pp.

Singer, R. 1976. Marasmieae (Basidiomycetes-Tricholomataceae). Flora Neotropica Monogr. 17: 1-347.

Tehon, L.R. 1924a. *Marasmius* on wheat. Mycologia 16: 132-133.

Tehon, L.R. 1924b. A preliminary report on the occurrence and distribution of the common bacterial and fungous diseases of crop plants in Illinois. Bull. Illinois Nat. Hist. Surv. 15: 173-325.

Young, P.A. 1925. A *Marasmius* parasitic on small grains in Illinois. Phytopath. 15: 115-118.

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BLUFF SPRING FEN NATURE PRESERVE: CHECKLIST OF VASCULAR PLANT TAXA

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ABSTRACT

A checklist of the vascular plant taxa observed at Bluff Spring Fen Nature Preserve, Cook County, Illinois is reported. It includes 69 families, 229 genera, and 396 infraspecific taxa.

This paper documents the plant taxa reported from Bluff Spring Fen Nature Preserve, an area of 36 hectares (90 acres) located in Hanover Township, Cook County, Illinois, just southeast of Elgin (T41N, R9W, N½, Sec. 30). Included in the area are two kames and an extensive disturbed oak woodland. The plant communities (graminoid fen, shrub fen, calcareous seep, wet-mesic prairie, sedge meadow, *Typha-Carex* community, dry gravel prairie, and shrub community), vegetation history, and management of the preserve were recently described (Stoynoff and Hess, 1986).

Voucher specimens to document the plant taxa present in the entire nature preserve were collected during the last several years and deposited in the herbarium of The Morton Arboretum (MOR). The flora includes 69 families, 229 genera, and 396 species, subspecies, and varieties. The largest families are the Asteraceae with 56 species, the Poaceae with 43 species, and the Cyperaceae with 36 species. *Carex*, *Aster*, and *Solidago* are the largest genera with 21, eight, and eight species, respectively. We continue to collect sight records as they are relocated.

It has been brought to our attention by an anonymous reviewer that an additional ten acres of sedge meadow and oak woodland are now included within the nature preserve. The addition is reported to have perhaps a dozen or more taxa

such as *Camassia scilloides, Carex sprengelli, Erigeron pulchellus,* and *Panicum latifolium* [*Dichanthelium latifolium*]. We have not included these taxa in this list, because we have neither examined this area, nor vouchers for the plants.

Nine taxa in this checklist are recorded as endangered or threatened for Illinois (Natural Land Institute, 1981). The endangered species are *Carex crawei, Triglochin palustre, Cypripedium candidum, Asclepias lanuginosa,* and *Utricularia intermedia.* (We are informed (anonymous reviewer) that after a prescribed burning, the endangered *Pogonia ophioglossoides* was found. It was not vouchered and hence not included in this list, but is mentioned because it is an important find.) The four threatened species are *Calopogon tuberosus, Cladium mariscoides, Eleocharis rostellata,* and *Tofieldia glutinosa.* Endangered and threatened taxa are preceded by an asterisk (*). Adventive taxa to the Bluff Springs Fen Nature Preserve are preceded by an exclamation point (!). Nomenclature primarily follows Kartesz and Kartesz (1980). Exceptions are based upon U. S. Department of Agriculture (1982), and Swink and Wilhelm (1979). The synonyms are included within brackets ([]).

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PTERIDOPHYTA

Equisetaceae
- *Equisetum arvense* L.
- *E. fluviatile* L.
- *E. hyemale* L. var. *affine* (Engelm.) A. A. Eat.
- *E. laevigatum* A. Braun
- *E.* x *nelsonii* (A. A. Eat.) Schaffn.

MAGNOLIOPHYTA

LILIOPSIDA

Alismataceae
- *Alisma plantago-aquatica* L.
- *Sagittaria latifolia* Willd.

Amaryllidaceae
- *Hypoxis hirsuta* (L.) Coville

Araceae
- *Arisaema triphyllum* (L.) Schott
- *Symplocarpus foetidus* (L.) Nutt.

Commelinaceae
- *Tradescantia ohiensis* Raf.

Cyperaceae
- *Carex bebbii* (Bailey) Fern.
- *C. cephalophora* Willd.
- *C. comosa* Boott
- *C. convoluta* Mackenz.
- °*C. crawei* Dew.
- *C. granularis* Muhl. ex Willd.
- *C. haydenii* Dew.
- *C. hystericina* Muhl. ex Willd.
- *C. lanuginosa* Michx.
- *C. leptalea* Wahlenb.
- *C. molesta* Mackenz.
- *C. pensylvanica* Lam.
- *C. prairea* Dew.
- *C. sterilis* Willd.
- *C. stipata* Muhl. ex Willd.
- *C. stricta* Lam. var. *strictior* (Dewey) J. Carey
- *C. tenera* Dew.
- *C. tetanica* Schkuhr
- *C. trichocarpa* Schkuhr
- *C. umbellata* Schkuhr ex Willd.
- *C. vulpinoidea* Michx.
- °*Cladium mariscoides* (Muhl.) Torr.
- *Cyperus filiculmis* Vahl
- *C. rivularis* Kunth

Eleocharis elliptica Kunth
E. erythropoda Steudel
E. intermedia Schultes
°*E. rostellata* (Torr.) Torr.
E. smallii Britt.
E. tenuis (Willd.) Schultes
Eriophorum angustifolium Honck.
Rhynchospora capillacea Torr.
Scirpus acutus Muhl. ex Bigelow
S. *atrovirens* Willd.
S. *validus* Vahl var. *creber* Fern.
[*S. tabernaemontanii* K. C. Gmel.]
Scleria verticillata Muhl. ex Willd.

Iridaceae
Iris virginica L. var. *shrevei* (Small) E. Anders.
Sisyrinchium albidum Raf.

Juncaceae
Juncus brachycephalus (Engelm.) Buch.
J. dudleyi Wieg. [*J. tenuis* Willd. var. *uniflorus* (Farw.) Farw.]
J. effusus L. var. *solutus Fern. & Wieg.*
J. nodosus L.
J. tenuis Willd.
J. torreyi Coville

Juncaginaceae
°*Triglochin palustre* L.

Lemnaceae
Lemna minor L.

Liliaceae
Allium canadense L.
A. cernuum Roth
!*Asparagus officinalis* L.
!*Convallaria majalis* L.
!*Hemerocallis fulva* (L.) L.
Lilium michiganense Farw.
Polygonatum biflorum (Walt.) Ell.
Smilacina racemosa (L.) Desf.
S. *stellata* (L.) Desf.
Smilax lasioneuron Hook.
°*Tofieldia glutinosa* (Michx.) Pers.
Trillium recurvatum Beck

Orchidaceae
°*Calopogon tuberosus* (L.) B.S.P.
°*Cypripedium candidum* Muhl. ex Willd.
Liparis loeselii (L.) Richard
Platanthera hyperborea (L.) Lindl. var. *huronensis* (Nutt.) Luer
Spiranthes cernua (L.) L. C. Rich.

Poaceae
!*Agropyron repens* (L.) Beauv.
A. trachycaulum (Link) Malte ex H. F. Lewis
!*Agrostis gigantea* Roth [*A. stolonifera* L.]
A. stolonifera L. var. *palustris* (Huds.) Farw.
Andropogon gerardii Vitman
Bouteloua curtipendula (Michx.) Torr.
Bromus ciliatus L.
!*B. inermis* Leyss.
!*B. japonicus* Thunb. ex Murr.
Calamagrostis canadensis (Michx.) Beauv.
!*Dactylis glomerata* L.
Deschampsia cespitosa (L.) Beauv.
Dichanthelium acuminatum (Sw.) Gould & Clark var. *implicatum* (Scribn.) Gould & Clark
D. oligosanthes (Schultes) Gould var. *scribnerianum* (Nash) Gould
!*Digitaria ischaemum* (Schreb. ex Schweig.) Schreb. ex Muhl.
Echinochloa crusgalli (L.) Beauv.
Elymus canadensis L.
E. villosus Muhl. ex Willd.
E. virginicus L.
Eragrostis spectabilis (Pursh) Steud.
!*Festuca elatior* L.
Glyceria striata (Lam.) A. S. Hitchc.
Hierochloe odorata (L.) Beauv.
Hystrix patula Moench
Leersia oryzoides (L.) Sw.
Muhlenbergia glomerata (Willd.) Trin.
M. mexicana (L.) Trin.
Panicum capillare L.
P. flexile (Gattinger) Scribn.
P. virgatum L.
Phalaris arundinacea L.
!*Phleum pratense* L.
Phragmites australis (Cav.) Trin. ex Steudel
!*Poa compressa* L.
!*P. pratensis* L.
Schizachyrium scoparium (Michx.) Nash
!*Setaria faberi* Herrm.
!*S. glauca* (L.) Beauv.
!*S. viridis* (L.) Beauv.
Sorghastrum nutans (L.) Nash
Spartina pectinata Link
Sphenopholis obtusata (Michx.) Scribn. var. *major* (Torr.) K. S. Erdman
Sporobolus heterolepis (Gray) Gray

Sparganiaceae
Sparganium eurycarpum Engelm.

Typhaceae
Typha angustifolia L.
T. latifolia L.

MAGNOLIOPSIDA

Aceraceae
Acer negundo L. var. *violaceum* J. Miller
!*A. platanoides* L.

Anacardiaceae
Rhus glabra L.
R. typhina L.
Toxicodendron radicans (L.) Kuntze

Apiaceae
Angelica atropurpurea L.
Berula erecta (Huds.) Coville

Cicuta bulbifera L.
!*Daucus carota* L.
Oxypolis rigidior (L.) Raf.
Sanicula canadensis L.

Apocynaceae
Apocynum cannabinum L. var. *hypericifolium* Gray

Aristolochiaceae
Asarum canadense L.

Asclepiadaceae
Asclepias incarnata L.
•*A. lanuginosa* Nutt. [*A. otarioides* Fourn.]
A. syriaca L.
A. tuberosa L.
A. verticillata L.

Asteraceae
!*Achillea millefolium* L.
Ambrosia artemisiifolia L. var. *elatior* (L.) Desc.
A. trifida L.
!*Arctium minus* Bernh.
Artemisia caudata Michx. [*A. campestris* L. ssp. *caudata* (Michx.) Hall & Clements]
Aster azureus Lindl.
A. firmus Nees
A. lateriflorus (L.) Britt.
A. novae-angliae L.
A. pilosus Willd.
A. puniceus L.
A. sagittifolius Wed. ex Willd. [*Aster* x *sagittifolius* Wed. ex Willd.]
A. umbellatus P. Mill.
Bidens cernua L.
B. comosa (Gray) Wieg.
B. vulgata Greene
Brickellia eupatorioides (L.) Shinners var. *corymbulosa* (T. & G.) Shinners
!*Cichorium intybus* L.
Cirsium altissimum (L.) Spreng.
!*C. arvense* (L.) Scop.
C. muticum Michx.
!*C. vulgare* (Savi) Tenore
Erigeron annus (L.) Pers.
E. philadelphicus L.
E. strigosus Muhl. ex Willd.
Eupatorium altissimum L.
E. maculatum L.
E. perfoliatum L.
E. rugosum Houtt.
Helenium autumnale L.
Helianthus giganteus L.
H. grosseserratus Martens
!*Leucanthemum vulgare* Lam.
Liatris pycnostachya Michx.
Prenanthes racemosa Michx.
Ratibida pinnata (Vent.) Barnh.
Rudbeckia hirta L.
R. laciniata L.
R. triloba L.
Senecio aureus L.
S. pauperculus Michx.
Silphium integrifolium Michx.
S. perfoliatum L.
S. terebinthinaceum Jacq.
Solidago altissima L. [*S. canadensis* L. var. *scabra* (Muhl.) T. & G.]
S. gigantea Ait.
S. nemoralis Ait.
S. ohioensis Riddell
S. patula Muhl.
S. riddellii Frank
S. rigida L.
S. uiliginosa Nutt.
!*Sonchus arvensis* L. ssp. *uliginosus* (Bieb.) Nyman
!*Taraxacum officinale* Weber
!*Tragopogon major* Jacq. [*T. dubius* Scop. ssp. *major* (Jacq.) Voll.]
Vernonia fasciculata Michx.

Balsaminaceae
Impatiens capensis Meerb.

Betulaceae
Corylus americana Walt.

Bignoniaceae
!*Catalpa speciosa* (Warder ex Barney) Engelm.

Boraginaceae
!Cynoglossum officinale L.
Hackelia virginiana (L.) I. M. Johnst.
!*Lappula echinata* Gilib.
Lithospermum canescens (Michx.) Lehm.
L. incisum Lehm.
!*Myosotis scorpioides* L.

Brassicaceae
Arabis laevigata (Muhl.) Poir.
!*Barbarea vulgaris* R. Br.
Cardamine bulbosa (Schreb.) B.S.P.
!*Erysimum inconspicuum* (S. Wats.) MacM.
!*Lepidium densiflorum* Schrad.
!*Lobularia maritima* (L.) Desv.
!*Nasturtium officinale* R. Br.

Campanulaceae
Campanula americana L.
C. aparinoides Pursh
Lobelia kalmii L.
L. siphilitica L.
L. spicata Lam.

Caprifoliaceae
!*Lonicera* x *minutiflora* Zabel
!*L.* x *muendeniensis* Rehder
L. prolifera (Kirchn.) Rehder
!*L. tatarica* L.
Sambucus canadensis L.
Triosteum perfoliatum L.
Viburnum lentago L.
!*V. opulus* L.
V. rafinesquianum Schultes

Caryophyllaceae
Arenaria stricta Michx. [*Minuartia michauxii* (Fern.) Farw.]
!*Dianthus armeria* L.

!*Saponaria officinalis* L.
!*Silene cserei* Baumg.
S. stellatta (L.) Ait. f.

Chenopodiaceae
!*Atriplex patula* L.

Clusiaceae
!*Hypericum perforatum* L.
H. pyramidatum Ait.

Convolvulaceae
Calystegia sepium (L.) R. Br.
Cuscuta cephalanthii Engelm.
C. glomerata Choisy

Cornaceae
Cornus amomum Mill. ssp. *obliqua* (Raf.) Wilson
C. foemina Mill. ssp. *racemosa* (Lam.) Wilson
C. stolonifera Michx. [*C. sericea* L. ssp. *sericea*]

Euphorbiaceae
Euphorbia corollata L.
!*E. maculata* L.

Fabaceae
Amorpha canescens Pursh
Amphicarpaea bracteata (L.) Fern.
Apios americana Medic.
Astragalus canadensis L.
Dalea purpurea Vent.
Desmodium canadense (L.) DC.
!*Gleditsia triacanthos* L.
Lathyrus palustris L.
!*Medicago lupulina* L.
!*Melilotus alba* Medic.
!*M. officinalis* (L.) Pallas
!*Trifolium hybridum* L.
!*T. pratense* L.
!*T. repens* L.

Fagaceae
Quercus alba L.
Q. ellipsoidalis E. J. Hill
Q. macrocarpa Michx.
Q. rubra L.
Q. velutina Lam.

Gentianaceae
Gentiana andrewsii Griseb.
Gentianopsis procera (Th. Holm) Ma

Geraniaceae
Geranium maculatum L.

Hippocastanaceae
Aesculus glabra Willd.

Lamiaceae
Agastache scrophulariifolia (Willd.) Kuntze
!*Glechoma hederacea* L.
Hedeoma hispidum Pursh
!*Leonurus cardiaca* L.
Lycopus americanus Muhl. ex Bart.
L. uniflorus Michx.
L. virginicus L.
Mentha arvensis L. var. *villosa* (Benth.) S. R. Stewart
Monarda fistulosa L.
!*Nepeta cataria* L.
Prunella vulgaris L. var. *lanceolata* (Bart.) Fern.
Pycnanthemum virginianum (L.) Durand & Jackson
Scutellaria galericulata L.
S. lateriflora L.
S. leonardii Epl.
Stachys palustris L. var. *homotricha* Fern.
S. tenuifolia Willd. var. *hispida* (Pursh) Fern.
Teucrium canadense L.

Lentibulariaceae
°*Utricularia intermedia* Hayne
U. vulgaris L.

Linaceae
Linum sulcatum Riddell

Lythraceae
!*Lythrum salicaria* L.

Moraceae
!*Morus alba* L.

Oleaceae
Fraxinus pennsylvanica Marsh. var. *pennsylvanica*
F. pennsylvanica Marsh. var *subintegerrima* (Vahl) Fern.

Onagraceae
Circaea lutetiana L. ssp. *canadensis* (L.) Asch. & Magnus
Epilobium coloratum Biehler
!*E. hirsutum* L.
Gaura biennis L.
Oenothera biennis L.

Oxalidaceae
Oxalis europaea Jord.
O. stricta L.
O. violacea L.

Papaveraceae
Sanguinaria canadensis L.

Plantaginaceae
!*Plantago lanceolata* L.
P. rugelii Dcne.

Polemoniaceae
Polemonium reptans L.

Polygonaceae
!*Polygonum achoreum* Blake
!*P. convolvulus* L.
P. pensylvanicum (L.) Small
!*P. persicaria* L.
P. punctatum Ell.
P. scandens L.
!*Rheum rhaponticum* L.
!*Rumex crispus* L.
R. orbiculatus Gray

Primulaceae
Dodecatheon meadia L.
Lysimachia ciliata L.
L. quadriflora Sims

Ranunculaceae
Actaea rubra (Ait.) Willd.
Anemone canadensis L.
A. cylindrica Gray
A. quinquefolia L. var. *interior* Fern.
A. virginiana L.
Aquilegia canadensis L.
!*A. vulgaris* L.
Caltha palustris L.
Clematis virginiana L.
Ranunculus abortivus L.
R. fascicularis Muhl. ex Bigelow
R. pensylvanicus L. f.
Thalictrum dasycarpum Fisch. & Lall. var. *dasycarpum*
T. dasycarpum Fisch. & Lall. var. *hypoglaucum* (Rydb.) Boiv.

Rhamnaceae
!*Rhamnus cathartica* L.
!*R. frangula* L.

Rosaceae
Agrimonia gryposepala Wallr.
A. pubescens Wallr.
Amelanchier sanguinea (Pursh) DC.
Crataegus crus-galli L.
C. mollis (T. & G.) Scheele
Fragaria virginiana Duchesne
Geum canadense Jacq.
G. laciniatum Murr. var. *trichocarpum* Fern.
G. triflorum Pursh
Potentilla arguta Pursh
P. fruticosa L.
P. norvegica L.
!*P. recta* L.
P. simplex Michx.
Prunus serotina Ehrh.
P. virginiana L.
Rosa arkansana Porter var. *suffulta* (Greene) Cockerell
R. blanda Ait.
R. carolina L.
Rubus occidentalis L.
R. pensilvanicus Poir.

Rubiaceae
Galium aparine L.
G. asprellum Michx.
G. boreale L.
G. trifidum L.

Salicaceae
!*Populus alba* L.
P. deltoides Bartr. ex Marsh.
P. tremuloides Michx.
Salix amygdaloides Anderss.
S. bebbiana Sarg.
S. discolor Muhl.
S. exigua Nutt.
!*S. fragilis* L.
S. myricoides Muhl.
S. rigida Muhl.

Santalaceae
Comandra richardsiana Fern.

Saxifragaceae
Heuchera richardsonii R. Br.
Parnassia glauca Raf.
Penthorum sedoides L.
Ribes americanum P. Mill.
R. missouriense Nutt. ex T. & G.
Saxifraga pensylvanica L.

Scrophulariaceae
!*Agalinis skinneriana* (Wood) Britt.
Aureolaria grandiflora (Benth.) Pennell var. *pulchra* Pennell
Chelone glabra L.
!*Linaria vulgaris* P. Mill.
Pedicularis lanceolata Michx.
!*Verbascum thapsus* L.
Veronicastrum virginicum (L.) Farw.

Solanaceae
!*Datura innoxia* Mill.
Physalis virginiana Mill.
!*Solanum americanum* Mill.
!*S. dulcamara* L.

Tiliaceae
Tilia americana L.

Ulmaceae
Ulmus americana L.
U. rubra Muhl.

Urticaceae
Laportea canadensis (L.) Weddell
Pilea fontana (Lunell) Rydb.
Urtica dioica L. ssp. *gracilis* (Ait.) Seland. var. *procera* (Muhl.) Weddell

Valerinaceae
Valeriana edulis Nutt. ex T. & G. ssp. *ciliata* (T. & G.) F. G. Mey.

Verbenaceae
Phryma leptostachya L.
Verbena simplex Lehm.
V. stricta Vent.
V. urticifolia L.

Violaceae
Viola affinis Le Conte
V. septentrionalis Greene

Vitaceae
Parthenocissus quinquefolia (L.) Planch.
Vitis riparia Michx.

LITERATURE CITED

Kartesz, J.T. & R. Kartesz. 1980. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. The University of North Carolina Press, Chapel Hill, N. Carolina. 500 pp.

Natural Land Institute. 1981. Endangered and threatened vertebrate animals and vascular plants of Illinois. Ill. Dept. Conserv., Springfield, Ill. 189 pp.

Stoynoff, N.A. & W.J. Hess. 1986. Bluff City Fen: Communities, vegetation history, and management. Trans. Ill. State Acad. Sci. 79(1 & 2):53-58.

Swink, F. & G. Wilhelm. 1979. Plants of the Chicago Region. The Morton Arboretum, Lisle, Illinois. 922 pp.

U. S. Department of Agriculture. 1982. National list of scientific plant names. Soil Conserv. Serv. SCS-TP-159. 2 vol.

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SEASONAL VARIATION OF CYANIDE PRODUCTION IN THREE ILLINOIS PLANT SPECIES

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ABSTRACT

Two populations each of *Phlox divaricata* L., *Mertensia virginica* (L.) Pers., and *Celtis occidentalis* L. from east-central Illinois were examined for cyanide production. The frequency and amount of cyanide produced was found to vary seasonally among the individuals tested within each population of each species. All three taxa peaked in cyanide production during the first two weeks in May.

INTRODUCTION

Many plants are capable of synthesizing compounds which liberate hydrogen cyanide when hydrolyzed. This phenomenon, known as cyanogenesis, has been reported from bacteria, lichens, fungi, ferns, fern allies, gymnosperms, and at least 2050 species, representing more than 110 families of angiosperms (Gibbs, 1974; Hegnauer, 1959; Seigler, 1976; Tjon Sie Fat, 1979).

Cyanogenesis is a result of the hydrolysis of cyanoglucosides or cyanolipids that yield one or more sugars or fatty acids, aldehydes or ketones and hydrogen cyanide (HCN). The amount of hydrogen cyanide liberated depends on several intrinsic (genetics, plant organ, age and even sex of the plant) and extrinsic factors (climate, available moisture, soil fertility, and frost damage) (Seigler, 1976; Hegnauer, 1959). Although numerous plant species have been reported as cyanogenic, little information is available regarding the extent of cyanogenesis in natural populations. Several previously published works indicate a high degree of cyanogenic variability in populations of *Trifolium repens* L. (Daday, 1965), *Lotus corniculatus* L. (Jones, 1977), and *Lotus alpinus* L. (Urbanska, 1982), and *Ranunculus montanus* Willd. (Dickenmann, 1982).

The present study was initiated to determine the extent of cyanogenic variability in populations of *Phlox divaricata* L. (common phlox), *Mertensia virginica* (L.) Pers. (bluebells), and *Celtis occidentalis* L. (hackberry) to see if individual plants were consistently cyanogenic or if cyanogenesis was transitory during growth.

MATERIALS AND METHODS

The plants utilized in this study were taken from natural populations at Burgner Acres Natural Area located in the Grand Prairie Division of Illinois (Schwegman, 1973) three miles north of the Shelbyville Moraine in Coles County, Illinois (Sec 1 T12N R8E). Burgner Acres is a ten acre woodlot with a maximum difference in elevation of 6 m. The dominant upland species are *Quercus alba* L., *Carya ovata* (Mill.) K. Koch, and *Fraxinus americana* L. The dominant lowland species include *Celtis occidentalis* L. and *Fraxinus americana* (Lehnen and Ebinger, 1984).

One upland and one lowland population each of *Celtis occidentalis, Mertensia virginica,* and *Phlox divaricata* were studied for cyanogenesis. In each population 30 individuals were randomly selected and marked with numbered plastic nursery tags. A leaf from each numbered individual was tested on a weekly basis for the presence of hydrogen cyanide, the woodland phlox and bluebell populations from spring emergence until dormancy in early summer, the hackberry populations from leaf development until the first hard frost in the fall. In hackberry, the leaves were chosen from the branch which was tagged.

Individuals were tested for cyanide production using the Feigl-Anger technique (Feigl and Anger, 1966; Tantisewie *et al.*, 1969). A small amount of each leaf blade (about 200 mg) was crushed and placed in a small vial with 4-5 drops of distilled water and a drop of antibiotic solution (0.5 mM streptomycin sulfate). A strip of filter paper impregnated with copper ethylacetoacetate and tetra base (4,4'tetramethyldiaminodiphenylmethane) was suspended with a dry cork over the sample, taking care to avoid contact with the leaf-water mixture. The test samples were read and recorded after 24 hours at room temperature. Although a quantitative determination of cyanide was not made, the color changes give an indication of the amount of hydrogen cyanide released (Dickenmann, 1982). A light blue color on the lower part of the test strip indicates a weak reaction (about 2-20 mg HCN per kg fresh weight); a moderate reaction is indicated when most of the paper turns light blue (about 21-50 mg hch per kg fresh weight), and a strong reaction when the paper turns a dark blue throughout (more than 50 mg HCN per kg fresh weight).

RESULTS AND DISCUSSION

All of the species examined were polymorphic for cyanide production (Table 1). In addition, the ability of any one individual to be cyanogenic varied throughout the growing season. Overall, it was common for an individual to be cyanogenic one week and test negative for cyanogenesis the following week.

Phlox divaricata had the lowest frequency of cyanogenesis with only weakly positive tests recorded. Throughout the populations no individual tested positive during the early part of the growing season although a few individuals were found to be cyanogenic during flowering and seed set. In most instances an individual

tested positive for cyanogenesis only once during the growing season, although two individuals in the upland population tested positive on consecutive weeks.

The results for *Mertensia virginica* were similar to those found in woodland phlox. Like phlox, no positive tests were recorded during the early part of the growing season, and with the exception of two moderate reactions, the tests were all weakly positive. Cyanogenesis was also more frequent during flowering and seed set. Most individuals gave a positive test only once during the growing season with only one individual from the lowland population testing positive for cyanide production for two consecutive weeks.

The highest cyanogenic frequency was found in the *Celtis occidentalis* populations. About 80% of the individuals from the upland population and 77% of the individuals in the lowland population were positive for HCN production at some time during the study. Positive tests were obtained only through the first weeks of the growing season with no positive tests recorded between June 10 and leaf abscission. In hackberry, 38% of the individuals tested positive for two or more consecutive weeks. Moderate and strong reactions were recorded for 38% of the individuals tested during the study.

Individuals within populations of each of the species tested varied in the frequency and amount of HCN produced. All three taxa peaked in cyanide production during the first two weeks in May, indicated by the number and strength of reactions which occurred during this period

It is possible that the cyanogenic compounds may serve as storage structures for nitrogen accumulated under conditions favorable for rapid nitrogen cycling, such as the warm, wet conditions in early spring. Nitrogen stored in these compounds might be utilized by the plants when nitrogen becomes limiting (Dement and Mooney, 1974). Cyanogenic compounds may also afford some protection against generalist herbivores (Jones, 1972; 1978) especially in young tissues (Rhoades and Gates, 1976) and during reproductive stages (Janzen, 1971).

LITERATURE CITED

Daday, H. 1965. Gene frequencies in wild populations of *Trifolium repens* L. IV. Mechanism of natural selection. Heredity 20:355-365.

Dement, W.A. and H.A. Mooney. 1974. Seasonal variation in the production of tannins and cyanogenic glucosides in the chaparral shrub *Heteromeles arbutifolius*. Oecologia 15:65-76.

Dickenmann, R. 1982. Cyanogenesis in *Ranunculus montanus* s.l. from the Swiss Alps. Ber. Geobot. Inst. ETH, Stiftung Rubel. 49:56-75.

Feigl, F. and V. Anger. 1966. Replacement of benzidine by copper ethylacetoacetate and tetra base as spot-test reagent for hydrogen cyanide and cyanogen. Analyst 91:282-284.

Gibbs, R.D. 1974. Chemotaxonomy of Flowering Plants. Vol. I-IV. McGill-Queen's University Press, Montreal.

Hegnauer, R. 1959. Die verbrietung der Blausäure bei den Cormophyten. 3. Mitteilung. Die Blausäure-haltigen Gattungen. Pharm. Weekblad 94:248-262.

Janzen, D.H. 1971. Seed predation by animals. Ann. Rev. Ecol. Syst. 2:465-493.

Jones, D.A. 1972. Cyanogenic glycosides and their functions. Harborne, J.B., ed. Phytochemical Ecology. Academic Press, New York. pages 103-124.

Jones, D.A. 1977. On the polymorphism of cyanogenesis in *Lotus corniculatus* L. VII. The distribution of the cyanogenic forms in western Europe. Heredity 39:27-44.

Jones, D.A. 1978. Cyanogenesis in Plants and Animal Feeding. Harborne, J.B., ed. Biochemical aspects of plant and animal co-evolution. Academic Press, New York. pages 21-34.

Lehnen, L. and J.E. Ebinger. 1984. Woody vegetation at Burgner Acres, east-central Illinois: Composition and change since 1964. Trans. Ill. St. Acad. Sci. 77(1 & 2):35-42.

Rhoades, D.F. and R.G. Gates. 1976. Towards a general understanding of plant antiherbivore chemistry. Recent advances in Phytochemistry 10:168-213.

Schwegman, J. 1973. Comprehensive plan for the Illinois Nature Preserves System. Part 2: The natural divisions of Illinois. Illinois Nature Preserves Commission. Rockford, Illinois.
Seigler, D.S. 1976. Plants of the Northeastern United States that produce cyanogenic compounds. Econ. Bot. 30:395-407.
Tantisewie, B., H.W.L. Ruijgrok, and R. Hegnauer. 1969. Die Verbreitung der Blausäure bei den Cormophyten 5. Mitteilung: Uber Cyanogene Verbindungen bei den Parietales und ber einigen weiteren Sippen. Pharm. Weekblad 104:1341-1355.
Tjon Sie Fat, L.A. 1979. Contribution to the knowledge of cyanogenesis in Angiosperms. (Cyanogene verbindigen bij Poaceae, Commelinaceae, Ranunculaceae en Campanulaceae.) Ph.D. Dissertation. Rijksuniversiteit te Leiden.
Urbanska, K. 1982. Polymorphism of cyanogenesis in *Lotus alpinus* from Switzerland. I. Small-scale variability in phenotypic frequencies upon acidic silicate and carbonate. Ber. Geobot. Inst. ETH, Stiftung Rubel. 49:35-55.

Table 1. Percent of cyanogenic individuals in upland and lowland populations of *Phlox divaricata* (common phlox), *Mertensia virginica* (bluebells), and *Celtis occidentalis* (hackberry) at Burgner Acres Natural Area, Coles County, Illinois.

WEEK	UPLAND			LOWLAND		
(month/day)	phlox	bluebells	hackberry	phlox	bluebells	hackberry
4/11	—	—	—	—	—	—
4/18	10	—	—	—	—	—
4/28	3	—	—	3	7	17
5/03	3	13	23	10	13	67
5/12	10	3	63	3	20	50
5/20	—	—	17	—	—	17
5/28	—	—	—	—	—	3
6/03	—	—	—	—	—	3
6/10-10/12	—	—	—	—	—	—

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THE BRYOPHYTES OF KICKAPOO STATE PARK, VERMILION COUNTY, ILLINOIS

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ABSTRACT

A total of 46 bryophytes, including 42 mosses and 4 liverworts, were collected in Kickapoo State Park, Vermilion County, Illinois. Of these, 19 are reported for Vermilion County for the first time. The abundance of each species is reported.

INTRODUCTION

Kickapoo State Park is located in the Wabash Border Division in east-central Illinois, 6 miles west of Danville, (T19N & T20N, R12W) in Vermilion County (Schwegman, 1973). The park was founded in 1939 when 1,290 acres (522 ha) of abandoned, strip-mined land were purchased from the United Electric Coal Company. Additional purchases and land trades brought the total acreage to 2,843 (1150.6 ha). Extensive underground and strip mining occurred over a vast majority of the area before the State of Illinois acquired the land. The park now offers a variety of bryophyte habitats, ranging from dry, steep hillsides, to low, moist depressions. Included within the park are twenty-two ponds as well as the Middle Fork of the Vermilion River. Although no bryological studies in Kickapoo State Park had been undertaken prior to this study, a list of mosses from Vermilion County was prepared by Grant and Hague (1931). Hague and Drexler (1938) later reported 29 liverworts and 2 hornworts from 18 counties in Illinois, including Vermilion County, while McCleary and Redfearn (1979) mentioned 35 species of mosses from Vermilion County.

Only three reports have been found regarding bryophytes associated with strip mining in Illinois. Brewer and Triner (1956) reported bryophytes as uncommon on spoils in Perry County, Illinois, while Rastorfer (1981) found 33 bryophytes at a

reclaimed surface mine at Goose Lake State Park, Grundy County, Illinois. Rastorfer's study compared the relative abundance of species on constructed mine spoils (reclaimed) to those on abandoned mine spoils. He found that *Ceratodon purpureus* (Hedw.) Brid. and *Funaria hygrometrica* Hedw. were the predominant bryophyte invaders on reclaimed mine soils. Rastorfer also mentioned that mosses occurred in areas affected by the 1975-1978 reclamation effort only after the establishment of vascular plants. Chimney (1984) later reported *Ricciocarpus natans* (L.) Corda for the first time in a coal strip mine impoundment in Knox County, Illinois.

Bryophytes were collected from selected habitats at Kickapoo State Park during summer, 1987 and spring, 1988. Identifications were confirmed by Dr. Charles B. Arzeni and the specimens deposited in the Ernest L. Stover Herbarium, Eastern Illinois University (EIU). Nomenclature follows that of Crum and Anderson (1981) or Crum (1983) for the mosses and Conard (1979) for the liverworts and hornwort. The location, habitat, and abundance of each specimen was recorded at the time of collection. The abundance of each species was noted and categorized as common, occasional, infrequent, and rare.

Listed below are the species encountered along with their habitat and abundance at Kickapoo State Park, Vermilion County, Illinois. The numbers listed after each species are the collection numbers of the author unless otherwise noted. An asterisk (*) denotes the first report for Vermilion County, Illinois.

MOSSES:

**Amblystegium ripariam* (Hedw.) BSG. Rare; on soil bank next to Long Pond. KJL 3.

Amblystegium serpens (Hedw.) BSG Common; especially along the bank of the runoff stream from Long Pond. KJL 31.

**Amblystegium serpens* (Hedw.) BSG. var. *juratzkanum* (Schimp.) Rau & Herv. Rare; on twigs at ravine bottom north of the cemetery. KJL 95.

Amblystegium tenax (Hedw.) BSG. Rare; on sandstone rock in stream running into Clear Pond on east side. KJL 48, 49, 50, 51.

**Amblystegium trichopodium* (Schultz) Hartm. Rare; in water near concrete bridge west of the east entrance near Clear Pond. KJL 89.

Amblystegium varium (Hedw.) Lindb. Common; on soil along wooded trails. KJL 57.

**Anomodon attenuatus* (Hedw.) Hub. Common; at the base of trees; occasionally on soil. KJL 29, 45, 46, 65, 84, 85.

Anomodon minor (Hedw.) Furnr. Rare; at the base of a tree on the east bank of the Middle Fork River near the canoe exit point. KJL 24.

Anomodon rostratus (Hedw.) Schimp. Occasional; on tree bases near Redear Campsite and on soil on the bank of the Long Pond runoff. KJL 16, 30, 93.

Artichum angustatum (Brid.) BSG. Common; on trail edges and ridge bottoms. KJL 26, 36, 59, 61, 72, 92.

Aulacomnium heterostichum (Hedw.) BSG. Infrequent; on north facing slopes south of Clear Pond and north of the Cemetery. KJL 86, 94.

Barbula unguiculata Hedw. Infrequent; found on disturbed areas frequented by fishermen and along trails in open areas. KJL 1, 88.

Bartramia pomiformis Hedw. Rare; found on steep slope north of the cemetery (a large population). KJL 97.

Brachythecium acuminatum (Hedw.) Aust. Occasional; at the base of trees and on rotten logs. KJL 9, 58.

Brachythecium oxycladon (Brid.) Jaeg. & Sauerb. Common; very abundant on exposed soils. KJL 2, 17, 82.

**Brachythecium rivulare* BSG. Rare; found in seep area south of Clear Pond on slope. KJL 83.

Brachythecium salebrosum (Web. & Mohr) BSG. Common; throughout the park in shaded disturbed areas along trails. KJL 32, 55, 66.

Bryhnia graminicolor (Brid.) Grout. Infrequent; on steep bank south of Clear Pond along trail. KJL 81.

**Bryoandersonia illicebra* (Hedw.) Robins. Occasional; between road and river ridge; each population was relatively large. KJL 10.

**Campylium chrysophyllum* (Brid.) J. Lange. Occasional; west of Long Pond at the base of trees. KJL 60, 69, 80.

**Campylium hispidulum* (Brid.) Mitt. Common; on soil and occasionally at tree bases. KJL 19, 71.

Ceratodon purpureus (Hedw.) Brid. Rare; on soil of disturbed areas. KJL 54.

**Desmatodon obtusifolius* (Schwaegr.) Schimp. Rare; found on top of a concrete bridge wall just west of the east entrance of the park near Clear Pond. KJL 63.

Dicranella heteromalla (Hedw.) Schimp. Common; east of Clear Pond on the soil at the base of trees as well as along wooded trail. KJL 35, 43.

**Encalypta ciliata* Hedw. Rare; found in disturbed area along High Pond Trail. KJL 70.

Entodon seductrix (Hedw.) C.M. Common; on dead and living trees and on concrete base near mine shaft no. 6, as well as on soil. KJL 7, 18, 20, 42.

Eurhynchium hians (Hedw.) Sande-Lac. Rare; on soil by stream flowing from large field by visitors station just south of the bridge, and at the south end of Clear Pond at water's edge. KJL 28, 44.

**Fissidens taxifolius* Hedw. Common; found in the more heavily wooded areas of the western portion of the park. KJL 8, 33, 34, 62.

Grimmia apocarpa Hedw. Rare; on concrete bases near mine shaft number 6. KJL 100.

Hypnum lindbergii Mitt. Rare; on soil west of Long Pond road and south of the spillway in a recently cleared area. KJL 79.

Leskea gracilescens Hedw. Common; on hardwood trees. KJL 5, 6, 56, 64.

**Mnium affine* Bland.: Schwaergr. var. *ciliare* C.M. Rare; found on top of a steep bank above stream flowing into Clear Pond on the east side. KJL 39.

**Mnium affine* Bland.: Funck var. *rugicum* (Laur.) BSG. Rare; on ravine side between road and Long Pond. KJL 73.

Mnium cuspidatum Hedw. Common; throughout the park in heavily wooded areas on soil and decayed logs. KJL 4, 11, 41, 52, 75.

**Orthotrichum pusillum* Mitt. Common; on larger and older trees, especially on *Populus deltoides*. KJL 12, 21, 25, 37, 78.

**Orthotrichum strangulatum* P. Beauv. Rare; found once on exposed limestone rock north of the Cypress picnic area. KJL 91.

Physcomitrium pyriforme (Hedw.) Hampe. Common; abundant along road north of the camp ground and Long Pond. KJL 90.

Platygyrium repens (Brid.) BSG. Common; usually on fallen logs and on old trees. KJL 14, 40, 98.
Pohlia nutans (Hedw.) Lindb. Rare; along runoff from Long Pond. KJL 38.
Rhynchostegium serrulatum (Hedw.) Jaeg. and Sauerb. Occasional; moist soil in wooded areas and on rotten logs. KJL 22, 76.
**Thuidium recognitum* (Hedw.) Lindb. Common; found abundantly between the park road and the large ridge east of the river. KJL 15, 67.
**Weissia controversa* Hedw. Infrequent; on soil pile on High Pond Trail and at ravine bottom north of the cemetery. KJL 68b, 96.

LIVERWORTS AND HORNWORTS

Conocephalum conicum (L.) Lindb. Rare; on sandstone at Rock Cut Road. KJL 99.
**Frullania eboracensis* Gott. Occasional; on hardwood trees. KJL 13.
Lophocolea heterophylla (Schrad.) Dum. Infrequent; on very rotten logs in heavily wooded areas. KJL 23, 27, 68a, 74, 77.
**Notothylus orbicularis* (Schwein.) Sull. Rare; on exposed soil bank at the east edge of High Pond. (K. Puharich & S. Jenkins 12).

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LITERATURE CITED

Brewer, R. and E.D. Triner. 1956. Vegetational features of some strip mined land in Perry County, Illinois. Trans. Ill. St. Acad. Sci. 48:73-84.
Chimney, M.J. 1984. First report of *Ricciocarpus natans* (L.) Corda (Marchantiales:Ricciaceae) from a strip mine impoundment. Trans. Ill. St. Acad. Sci. 77:43-44.
Conard, H.S. (revised by P.L. Redfearn, Jr.) 1979. How to know the mosses and liverworts. 2nd ed. Wm. C. Brown Co. Publ., Dubuque, Iowa. xi + 301 p.
Crum, H.A. 1983. Mosses of the Great Lakes forest. 3rd ed. University of Michigan, Ann Arbor. 417 pages.
Crum, H.A. and L.E. Anderson. 1981. Mosses of Eastern North America. 2 Vol. Columbia Univ. Press, New York. 1328 p.
Grant, F.R. and S.M. Hague. 1931. A list of mosses from Vermilion County, Illinois. Trans. Ill. St. Acad. Sci. 24(2):122-123.
Hague, S.M. and R.V. Drexler. 1938. Recent collections of Illinois liverworts. Trans. Ill. St. Acad. Sci. 31:113-114.
McCleary, J.A. and P.L. Redfearn, Jr. 1979. Checklist of the mosses of Illinois. Trans. Ill. St. Acad. Sci. 72(2)25-51.
Rastorfer, J.R. 1981. Comparison and distribution patterns of bryophytes at a reclaimed surface mine in Grundy County, Illinois, with a list of vascular plants. Argonne National Laboratory / Land Reclamation Program — 16, Argonne, Illinois. 75p.
Schwegman, J.E. 1973. Comprehensive plan for the Illinois Nature Preserves System. Part 2: The natural divisions of Illinois. Illinois Nature Preserves Commission, Springfield, IL. 32p.

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WILDLIFE OPENINGS IN THE SHAWNEE NATIONAL FOREST AND THEIR CONTRIBUTION TO HABITAT CHANGE

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ABSTRACT

Maintained openings in otherwise forested habitat have traditionally been considered beneficial to many forms of wildlife, but there have been recent concerns regarding their possible contribution to forest fragmentation. Currently, >1,500 wildlife openings in the Shawnee National Forest occupy <1.0% of the total area. In this paper, we describe certain physical and vegetational characteristics of these openings. We also compare land use and habitat surrounding the openings to that which existed prior to their establishment.

Since the late 1950s, forested acreage within a 1 km radius of sampled openings increased from 67 to 83% while agricultural and open lands declined from 33 to 16%. It is anticipated that open habitat in the Forest will continue to decline. In our opinion, continued maintenance of a reasonable number of openings would benefit a variety of wildlife, help maintain distinctive remnant plant communities, and not necessarily impact forest-interior species.

INTRODUCTION

The Shawnee National Forest (SNF), in extreme southern Illinois, is a discontinuous and diverse patchwork of timbered areas and oldfields interspersed with private lands. The area offers unique opportunities for natural resource management in a state that is 95% privately owned. In 1956, the U.S. Forest Service and the Illinois Department of Conservation initiated a cooperative program to establish

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and maintain openings and water holes for wildlife in the SNF; >1,500 such openings currently exist.

Wildlife management has traditionally emphasized the creation and maintenance of "edge" and diversity as a means of enhancing habitat for various species (Leopold 1933). Openings in forested habitat are considered especially beneficial to white-tailed deer (*Odocoileus virginianus*) (McCaffery and Creed 1969), wild turkey (*Meleagris gallopavo*) (Healy and Nenno 1983) as well as other game and nongame species (McCaffery et al. 1981). Concerns have been raised, however, regarding the potential negative impacts of habitat fragmentation, especially forests (Robbins 1979, Harris 1984). Similar concerns surfaced during recently-conducted appellate hearings relating to the Proposed Land and Resource Management Plan for the SNF. Specifically, the role of wildlife openings in the SNF has been questioned as well as their possible contribution to forest fragmentation (Tetreault 1988, Hussar 1988).

The Cooperative Wildlife Research Laboratory, Southern Illinois University-Carbondale recently conducted an inventory, classification, and evaluation of all wildlife openings in the SNF (Overcash and Roseberry 1986, 1987). In addition, land use surrounding current wildlife openings was compared to that which existed prior to establishment of the openings. The purpose of this paper is to describe (1) wildlife openings in the SNF in terms of number, size, density, dominant vegetation, and management; and (2) general land use and habitat patterns prior to and following establishment of the openings.

STUDY AREA

The SNF occupies 105,865 ha or 31% of the area within the original purchase boundary (U.S. Forest Service 1985). Only about 40% of the land was forested when acquisition was begun by the U.S. Forest Service in 1933; much of the remainder consisted of abandoned, highly eroded, "worn-out" farmland (Soady 1965). At present, approximately 90% of the SNF is forested. Native oak-hickory (*Quercus-Carya*) is the predominant type, but there is a substantial component of introduced southern pine (*Pinus* spp.) especially in the eastern portion of the SNF.

Eight natural divisions as defined by physiography, flora, and fauna (Schwegman 1973) are represented: the Southern Till Plain, Wabash Border Bottomlands, Lower Mississippi River Bottomland, Greater Shawnee Hills, Lesser Shawnee Hills, Ozark Hills, Coastal Plain Cretaceous Hills and Coastal Plain Bottomland divisions. Wildlife openings occur in all but the Wabash Border and Coastal Plains Bottomland, with 90% in the unglaciated Shawnee and Ozark Hills Divisions.

Administratively, the SNF is divided into 4 ranger districts: Murphysboro, Jonesboro, Vienna, and Elizabethtown. These contain 26, 13, 35, and 26% of the openings, respectively.

METHODS

Wildlife openings (n = 1,572) within the SNF were inventoried during July 1984-December 1985. Data were obtained from onsite visits to >600 openings and from U.S. Forest Service topographic maps and records. Land use within a 0.5 km radius (78 ha) of 1,137 openings was measured from ASCS aerial photographs

(1:12,000 and 1:20,000 scale) using a dot grid. Categories identified included deciduous and coniferous forest, intertilled cropland, pasture/hayfield, open habitat (primarily oldfields, clearcuts, newly-established plantations, and other wildlife openings), and water. To assess land use change over time, a subset of 80 openings was selected using stratified random sampling to represent the various physiographic regions and forest types. Land use within a 1.0 km radius (314 ha) of these openings was determined from recent (1980-1986) aerial photographs and compared with that which existed prior to establishment of the opening (determined from 1956-1959 aerial photos). Past and present land use on the same area was compared by paired *t* test ($\alpha = 0.05$). The composite sample (25,120 ha) contained 20% of all openings in the SNF (312) and represented 24% of its total area.

FINDINGS

Number, Size, and Distribution of Openings

Of the 1,572 openings initially identified, 1,528 were being maintained as of January 1986. Average size of individual openings was 0.5 ha (range 0.1 - 4.9); most (55%) were 0.3 to 0.6 ha, 20% were ≤0.2 ha, and 25% were ≥0.7 ha. Total area occupied was 789 ha or 0.74% of the entire SNF. Opening density averaged 1/68 ha; however, distribution tended to be somewhat more clumped than uniform. Over half (51%) were within 0.5 km of 2-4 other maintained openings, although 34% were relatively isolated (0-1 other openings within a 0.5 km radius).

Current Management and Dominant Vegetation

Current management emphasizes conversion of former fescue-dominated openings to tame legumes, maintenance of desirable early-successional native vegetation, and limited establishment of cereal grains. Management practices include mowing, burning, discing, and seeding on a 1-4 year rotation. Vegetational composition of openings varied greatly depending on method and frequency of treatment. Approximately 11% reflected annual-early perennial stages of secondary succession characteristic of recently-disturbed sites; 21% were in the perennial-forb stage with some early woody invasion; while 6% were dominated by woody vegetation such as persimmon (*Diospyros virginiana*), sassafras (*Sassafras albidum*), and sumac (*Rhus* spp). An additional 15% were predominately fescue (*Festuca* spp.), 13% contained mostly tame legumes, and slightly over 2% were in cereal grains. A relatively high proportion (10%) were characterized by native warm-season grasses such as little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), and Indian grass (*Sorghastrum nutans*). These occurred primarily in the Cretaceous Hills and Southern Till Plain divisions. The remaining openings exhibited a variety of vegetational patterns depending on site conditions and past management history.

Surrounding Habitat

Habitat within 0.5 km of maintained openings was predominately forested. Deciduous forest occupied 70% of the total area sampled and coniferous forests 18%. Other nearby land-use types were open areas 6%, pasture and hayfields <4%, intertilled cropland 1%, and water <1%. A majority (62%) of the openings occurred in heavily forested (≥90%) settings; only 10% were in areas <75% forested.

Past and Present Conditions

Land use patterns in the vicinity of maintained openings in the 1980's were compared with conditions immediately prior to or shortly after their establishment in the late 1950's. During this 30-year period, there were significant increases in deciduous and coniferous forest and water, and significant declines in cropland, pasture/hay, and open areas (Table 1). The overall pattern of change reflected a substantial increase in forested land (67% to 83%), a moderate decline in agricultural areas (16% to 12%), and a large reduction in open habitat (17% to 4%) (Fig. 1). Similar trends were recorded in both the eastern (Elizabethtown and Vienna districts) and western portions (Murphysboro and Jonesboro districts) of the SNF. In the eastern region, open areas declined from 22% to 5% with much of the reduction apparently resulting from establishment of pine in former oldfields. In the more heavily-wooded western region, open areas declined from 12 to 4%. Based on our sampling, the amount of non-agricultural open habitat in the SNF declined from >17,000 ha in the late 1950's to <4,500 in the mid 1980's. Wildlife openings, which contributed insignificantly to the early total, now constitute an estimated 18% of the current open habitat in the SNF; the remainder represents recent clearcuts, young pine or tulip (*Liriodendron tulipifera*) plantations, and small scattered oldfields.

DISCUSSION

A program to develop and maintain wildlife openings in the SNF was initiated in 1956 by the U.S. Forest Service and the Illinois Department of Conservation. A relatively large (>1,500) number of openings currently exist although the total area involved is small (<1.0% of the Forest). In the 30-year period during which openings were being developed (ca 1956-1986), the SNF has become more heavily forested and less open due to establishment of pines in former oldfields, natural succession and maturation, wildfire suppression, and acquisition of private lands. It is anticipated that open habitat will continue to decline as the practice of clearcutting is reduced or eliminated, young plantations mature, and burning is discouraged. Maintained wildlife openings should, therefore, contribute increasingly to the total amount of grass/forb habitat that does remain and to those species that benefit from it. Also, it should not be overlooked that as fire suppression on Forest Service and private lands hastens the disappearance of remnant presettlement prairie or "barrens" plant communities (Hutchison and Johnson 1981), those maintained openings that exhibit such characteristics will become increasingly important ecologically.

It was not the purpose of this paper to evaluate management of maintained openings or their effect on wildlife in the SNF. We believe, however, that continued maintenance of 1200-1500 openings could enhance habitat for a variety of game and non-game species, and in some cases help maintain distinctive remnant plant communities while not necessarily impacting area-sensitive forest-interior avian species.

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LITERATURE CITED

Harris, L.D. 1984. The fragmented forest. Univ. Chicago Press, Chicago, Ill. 211pp.

Healy, W.M. and E.S. Nenno. 1983. Minimum maintenance versus intensive management of clearings for wild turkeys. Wildl. Soc. Bull. 11(2): 113-120.

Hussar, J. 1988. Shawnee Forest a conservation battlefield. Chicago Tribune, May 29, Sect. 3:12.

Hutchison, M.D. and M. Johnson. 1981. The natural character of township 15 South, Range 6 East of the 3rd Principal Meridian in Pope and Massac counties, Illinois. Natural Land Inst., 21pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, NY. 481pp.

McCaffery, K.R. and W.A. Creed. 1969. Significance of forest openings to deer in northern Wisconsin. Wisc. Dept. Nat. Resour. Tech. Bull. No. 44. 104pp.

McCaffery, K.R., J.E. Ashbrenner, and J.C. Moulton. 1981. Forest opening construction and impacts in northern Wisconsin. Wisc. Dept. Nat. Resour. Tech. Bull. No. 120. 41pp.

Overcash, J.L. and J.L. Roseberry. 1986. Classification, inventory and analysis of Shawnee National Forest wildlife openings. Ill. Dept. Conserv. Final Rept., Fed. Aid Proj. W-94-R. Study I, 180pp.

Overcash, J.L. and J.L. Roseberry. 1987. Evaluation of Shawnee National Forest wildlife openings. Ill. Dept. Conserv. Final Rept., Fed. Aid Proj. W-94-R. Study II, 121pp.

Robbins, C.S. 1979. Effect of forest fragmentation on bird populations. Pages 198-212 *in* Management of North Central and Northeastern Forests for Nongame Birds; Proc. of the Workshop. U.S. Forest Serv. Gen. Tech. Rept. NC-51. 268pp.

Schwegman, J.E. 1973. Comprehensive plan for the Illinois Nature Preserves System. Part 2. The natural divisions of Illinois. Ill. Nature Preserves Comm. 32pp.

Soady, F.W., Jr. 1965. The making of the Shawnee. Forest History 9(2):3-16.

Tetreault, F. 1988. Silence in the forest. Outdoor Highlights 16(19):6-12.

U.S. Forest Service. 1985. Draft Environmental Impact Statement, Land and Resource Management Plan, Shawnee National Forest. U.S.D.A. Forest Service, Eastern Region, Harrisburg, Illinois.

Table 1. Land use composition[a] in the vicinity of wildlife openings in the Shawnee National Forest, ca 1956 vs 1986.

Category	1956	1986	Change (%)	*P*
Deciduous	63.7	70.8	+7.1	<0.0001
Coniferous	3.6	12.5	+8.9	<0.0001
Cropland	3.9	2.6	-1.3	<0.01
Pasture/hay	12.3	9.0	-3.3	<0.001
Open	16.5	4.2	-12.3	<0.0001
Water	<0.1	0.9	+0.9	<0.05

[a]Mean percent composition within 1.0 km radius of 80 openings (total area sampled = 25,120 ha).

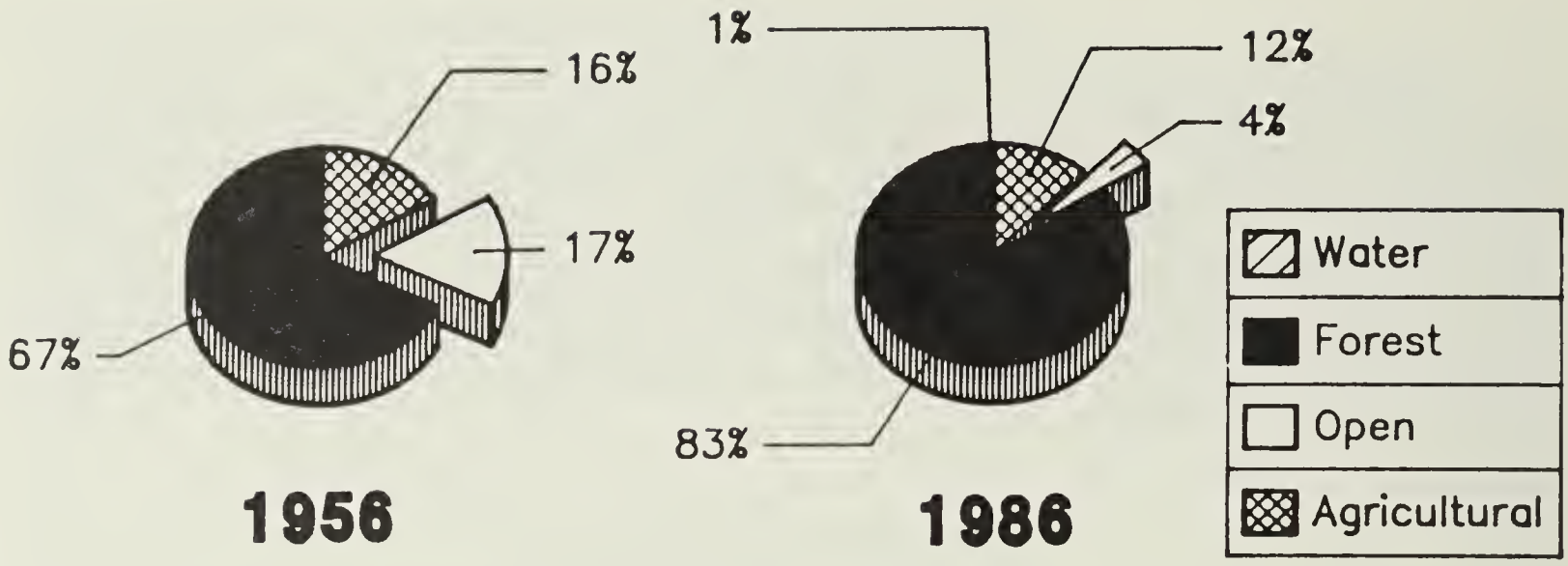

Figure 1. Land use changes in the vicinity of wildlife openings in the Shawnee National Forest, ca 1956 vs 1986.

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THE OCCURRENCE OF REGISPONGIA CONTORTA (KING) IN CHESTERIAN (UPPER MISSISSIPPIAN) ROCKS OF SOUTHERN ILLINOIS AND WESTERN KENTUCKY

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ABSTRACT

Specimens of calcareous sponges collected from Glen Dean, Menard, and Clore limestones (Chesterian) of southern Illinois and western Kentucky were identified as *Regispongia contorta* (King). These specimens represent the first reported occurrence of this genus and species in the Illinois Basin. They lived in a low energy, shallow marine shelf environment on a muddy bottom.

INTRODUCTION

Specimens of calcareous sponges were collected from the Glen Dean Limestone just upstream from the boat ramp, along the south side of the Ohio River, at Carrsville, Livingston County, Kentucky; from the Menard Limestone in the railroad cut just north of the railroad tunnel near Flatwoods, Johnson County, Illinois; and from a limestone in the Clore Formation in a draw about one mile northeast of Saratoga, Union County, Illinois (Center line NE ¼ SW ¼ SE ¼ Sec. 31, T. 11S., R.1 E.) in southern Illinois and western Kentucky. These specimens were identified as *Regispongia contorta* (King) based on their wall structure, wall thickness, shapes and size. They represent the first recorded occurrence of the genus and species in the Illinois Basin (Figures 1 and 2).

MATERIALS

The materials studied consist of seven complete or nearly complete and several fragmentary, calcareous sponge specimens (Figures 3-11).

PREVIOUS WORK

Sponges have previously been reported from rocks of Chesterian age in the Illinois Basin; however, a record of their identification and location has not been published. *R. contorta* was named *Wewokella contorta* by King (1943). Rigby (1978) recognized that *W. contorta*, while resembling *Wewokella solida* Girty, the type species for *Wewokella*, actually had a skeletal structure composed of polyactine spicules rather than the Y-shaped triactine spicules found in *W. solida*. On that basis Rigby established the genus *Regispongia* to include the species *contorta*. *R. contorta* has previously been reported from the "Jacksboro" limestone, Pennsylvanian of Texas by King (1943); from the Mississippian/Pennsylvanian Manning Canyon Shale of Utah by Rigby and Moyle (1959); from the Magdalena Formation, Lower Pennsylvanian of Texas by Nelson (1960); from the Gunsight Limestone Member of the Graham Formation, Pennsylvanian of Texas by Croneis and Toomey (1965); from the Vanport and Putnam Hill Limestones and the Mercer marine unit, Pennsylvanian of Ohio by Hoare and Sturgeon (1968); and from the Jensen Member of the Chainman Formation, Upper Mississippian/Lower Pennsylvanian of Utah by Rigby (1978). The present known range of the genus *Regispongia* is Late Mississippian (Chesterian) in Utah to Early Permian? (Wolfcampian) in Texas (Rigby, 1978).

TEXT

The specimens of *Regispongia contorta* studied range from elongate conical and sinuous to short cylindrical and contorted. The largest elongate conical specimen measures 117 mm. in length by 18 mm. in width (maximum) (Figure 3), while the largest cylindrical contorted specimen measures 44 mm. in length by 17.5 mm. in width (maximum) (Figure 8). Both shapes are characteristic of the species and occur together (Figures 3 and 4). These sponges have thick walls and long, narrow central cavities (Figures 7 and 8). The spécimens are well-preserved, but do bear heavy secondary calcification, which obscures some of the spicular structure. However, characteristic polyactine spicules are visible in some areas of the specimens studied (Figure 5). The specimens are found distributed on bedding planes singly or in clumps (Figure 9). They are aligned parallel to the bedding planes or sediment layers with one exception (Figure 6), but they are not oriented in any specific direction (Figure 9). Two specimens are distorted, especially one from Carrsville (Figure 11), because of compaction. *R. contorta* occurs in argillaceous micritic (Menard) or crinoidal biomicritic limestones (Glen Dean and Clore).

R. contorta was found in association with complete, articulated specimens of the brachiopod *Composita subquadrata* (Hall), "cup" plates of the crinoid *Agassizocrinus*, crinoid columnals, and fragments of fenestrate and ramose bryozoan colonies (Figures 10 and 11).

DISCUSSION

The occurrence of both elongate conical and cylindrical contorted specimens together, along with the fact that both bear polyactine spicules, suggests that shape is not a good criterion for speciation as was implied by some early workers (Croneis and Toomey, 1965). The well-preserved condition of the sponges and of *C. subquadrata* suggests that these specimens were not transported for any great distance, if at all. The randomly clumped, unoriented distribution as well as the fine preservation of these specimens also suggests that they were not subjected to strong current activity. The occurrence of *R. contorta* specimens in argillaceous micritic and crinoidal biomicritic limestones is indicative of muddy bottom conditions, because the specimens were not transported for any distance, if at all. And, the occurrence of *R. contorta* with *C. subquadrata,* a shallow marine shelf organism (Bretsky, 1968), indicates that *R. contorta* lived in a shallow marine shelf environment in the southern Illinois region. Low energy conditions also prevailed as indicated by fine preservation of fossils, little or no fossil transport, and lack of orientation of fossils on bedding planes.

CONCLUSIONS

Their polyactine spicules, thick walls, characteristic shapes, and size identify the calcareous sponges studied as *Regispongia contorta* (King).

These specimens represent the first recorded occurrence of the genus and species in the Illinois Basin.

Regispongia contorta lived in a low energy shallow marine shelf environment on a muddy bottom.

LITERATURE CITED

Bretsky, P.W., 1968, Evolution of Paleozoic Marine Invertebrate Communities, Science Vol. 159, p. 231-233, 1 text-fig.

Croneis, C. and D.F. Toomey, 1965, Gunsight (Virgilian) Wewokellid Sponges and Their Depositional Environment, Jour. Paleo. Vol. 39, p. 1-17, pls. 5-7.

Hoare, R.D. and M.T. Sturgeon, 1968, The Genus *Wewokella* (Proifera) in the Pennsylvanian of Ohio, Jour. Paleo. Vol. 42, p. 81-83, pl. 20.

King, R.H., 1943, New Carboniferous and Permian Sponges, State Geol. Surv. of Kansas Bull. 47, p. 27-28, pl. 2, figs. 1, 8 and pl. 3, fig 5.

Nelson, L.A., 1960, The Pennsylvanian Rocks of the Franklin Mountains East of Vinton, Texas, Roswell Geol. Soc. Guidebook Northern Franklin Mountains, southern San Andres Mountain, p. 131-134.

Rigby, J.K., 1978, Two Wewokellid Calcareous Sponges in North America, Jour. Paleo. Vol. 52, p. 705-716, 1 pl., 3 text-figs.

Rigby, J.K., and R.W. Moyle, 1959, Some Mississippian and Pennsylvanian Sponges from Utah, Jour. Paleo. Vol. 33, p. 399-403, pl. 56, text-fig. 1.

Swann, D.H., 1963, Classification of Genevievan and Chesterian (Late Mississippian) Rocks of Illinois, Illinois State Geol. Surv. R.I. 216, p. 8.

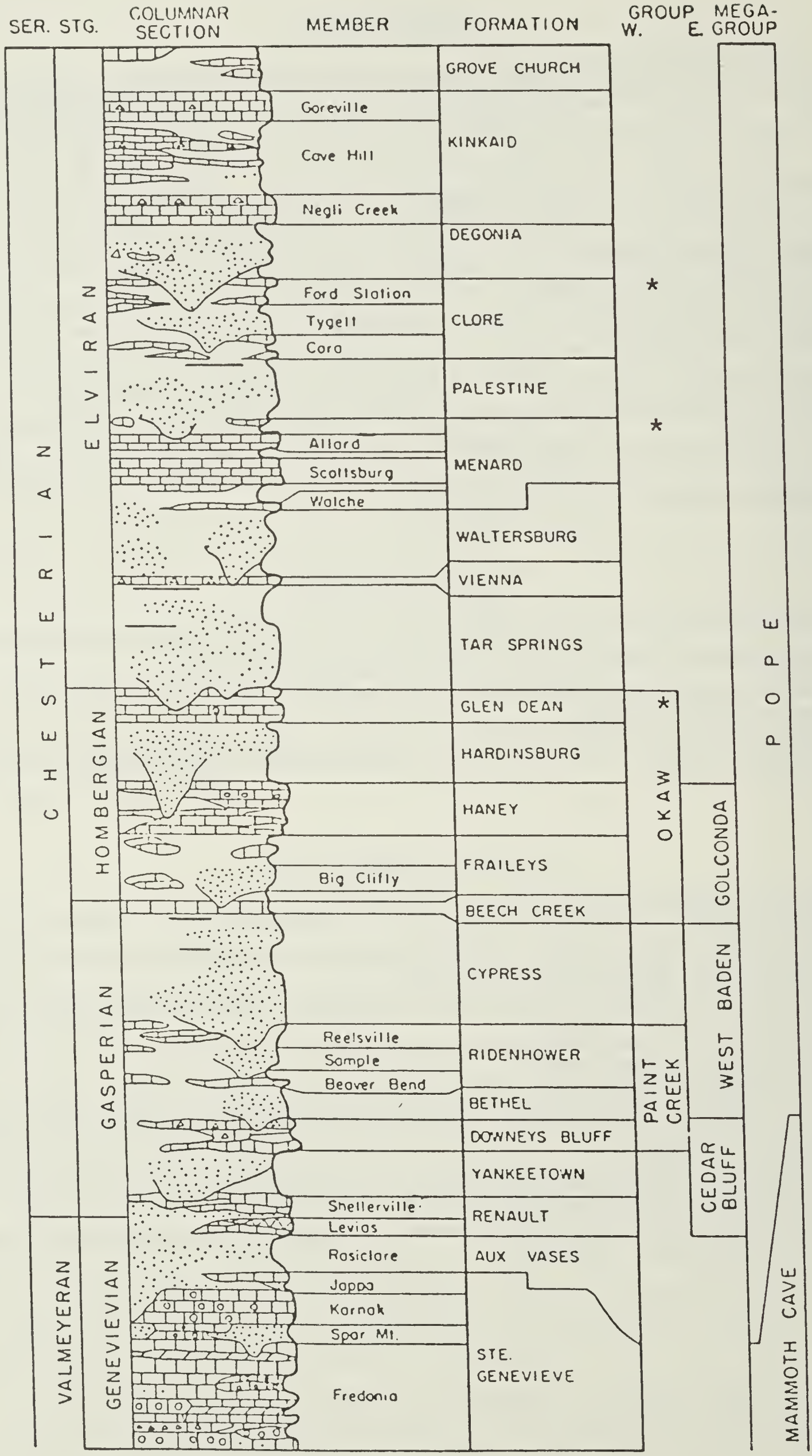

Figure 1. Columnar Section showing collecting levels (*). Swann, 1963

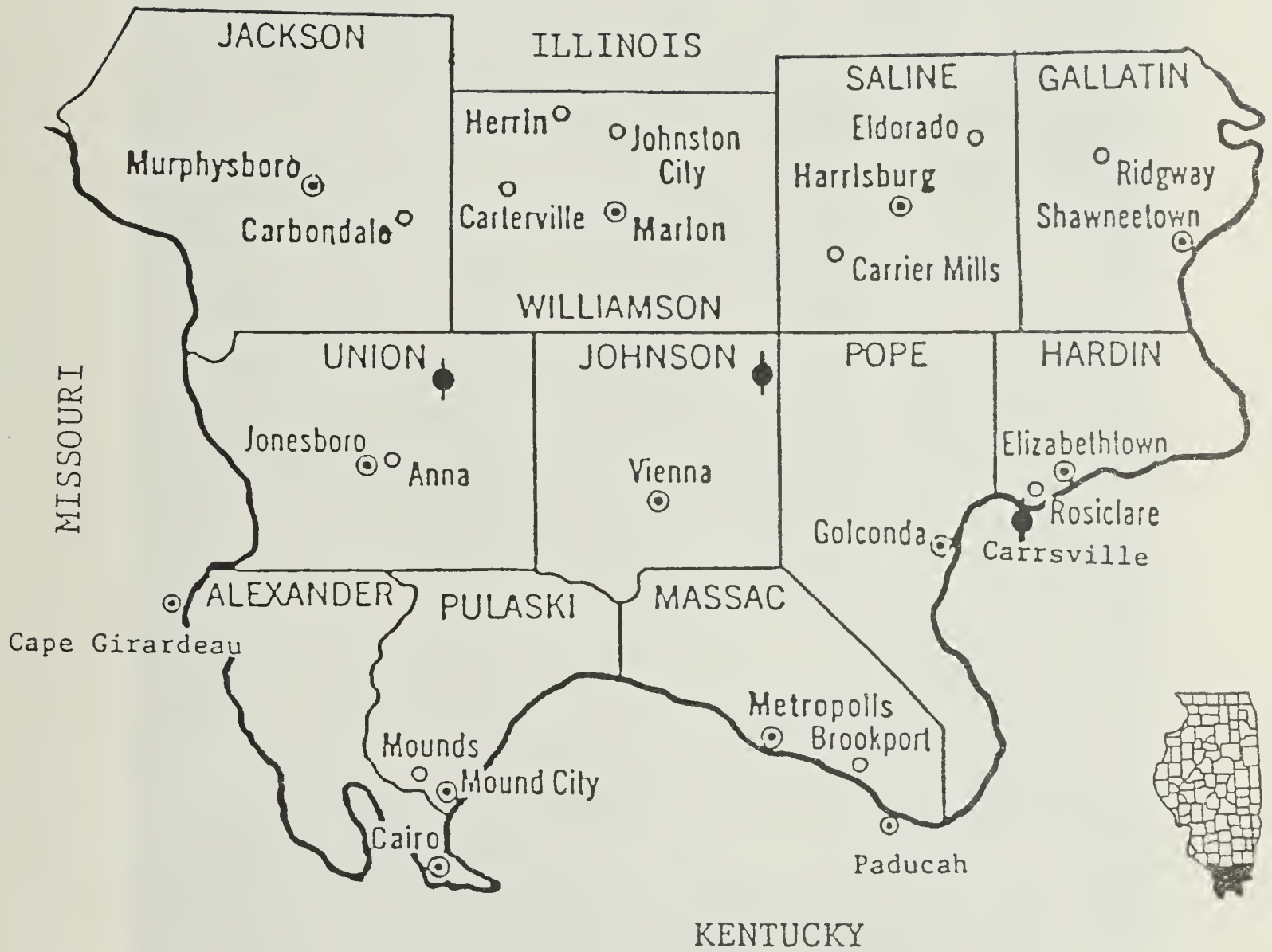

Figure 2. Locality Map showing collecting sites (✦).

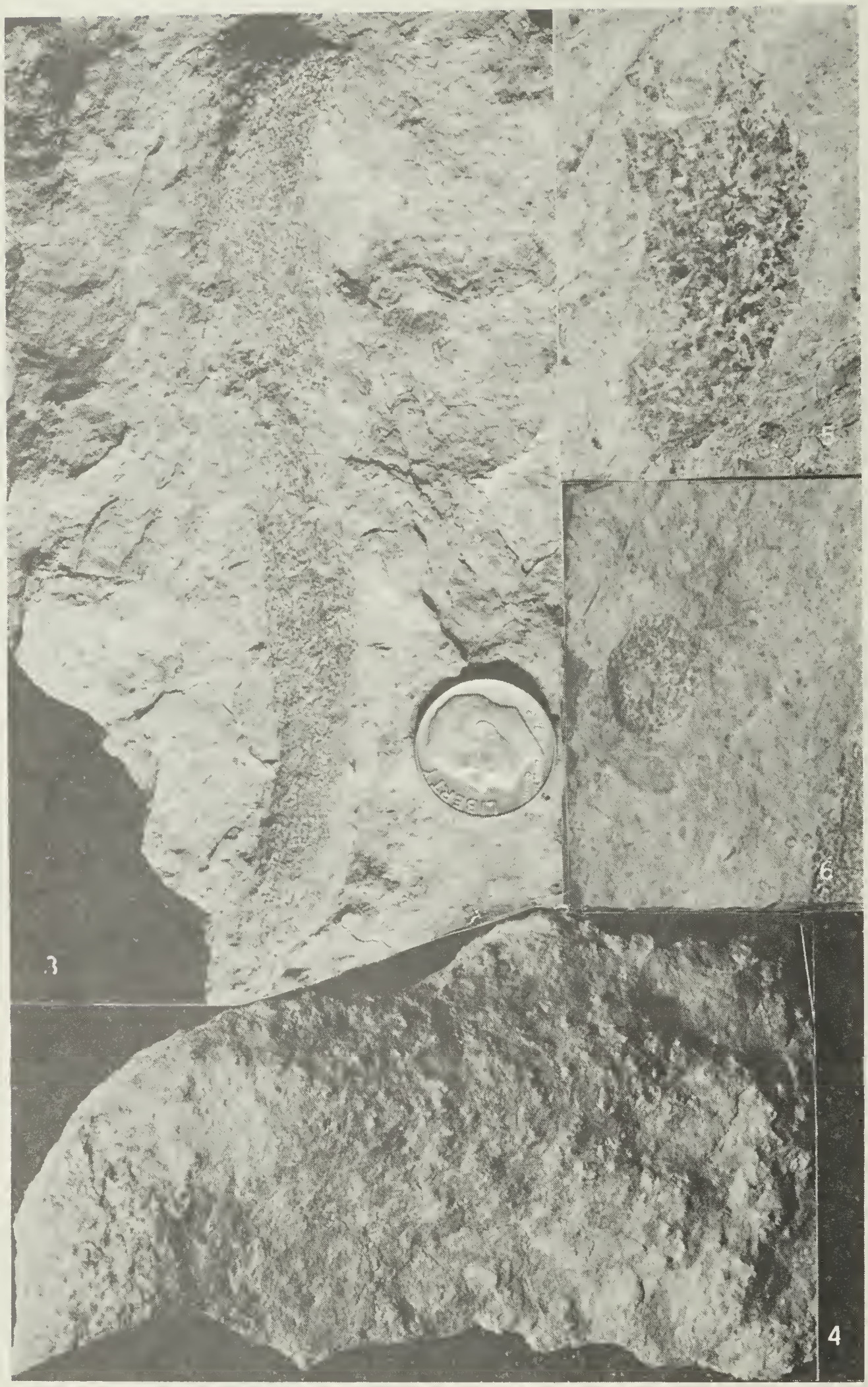

Figure 3. *Regispongia contorta,* lateral view of elongate conical form from the Menard X1, S.I.U.M.* 5184.

Figure 4. *Regispongia contorta,* lateral view of cylindrical contorted form from the Menard X2, S.I.U.M. 5185

Figure 5. *Regispongia contorta,* lateral view showing polyactine spicule in upper center of specimen from Clore X2, S.I.U.M. 4674.

Figure 6. *Regispongia contorta,* top view of nearly vertically oriented specimen from Clore X1.5, S.I.U.M. 4674.

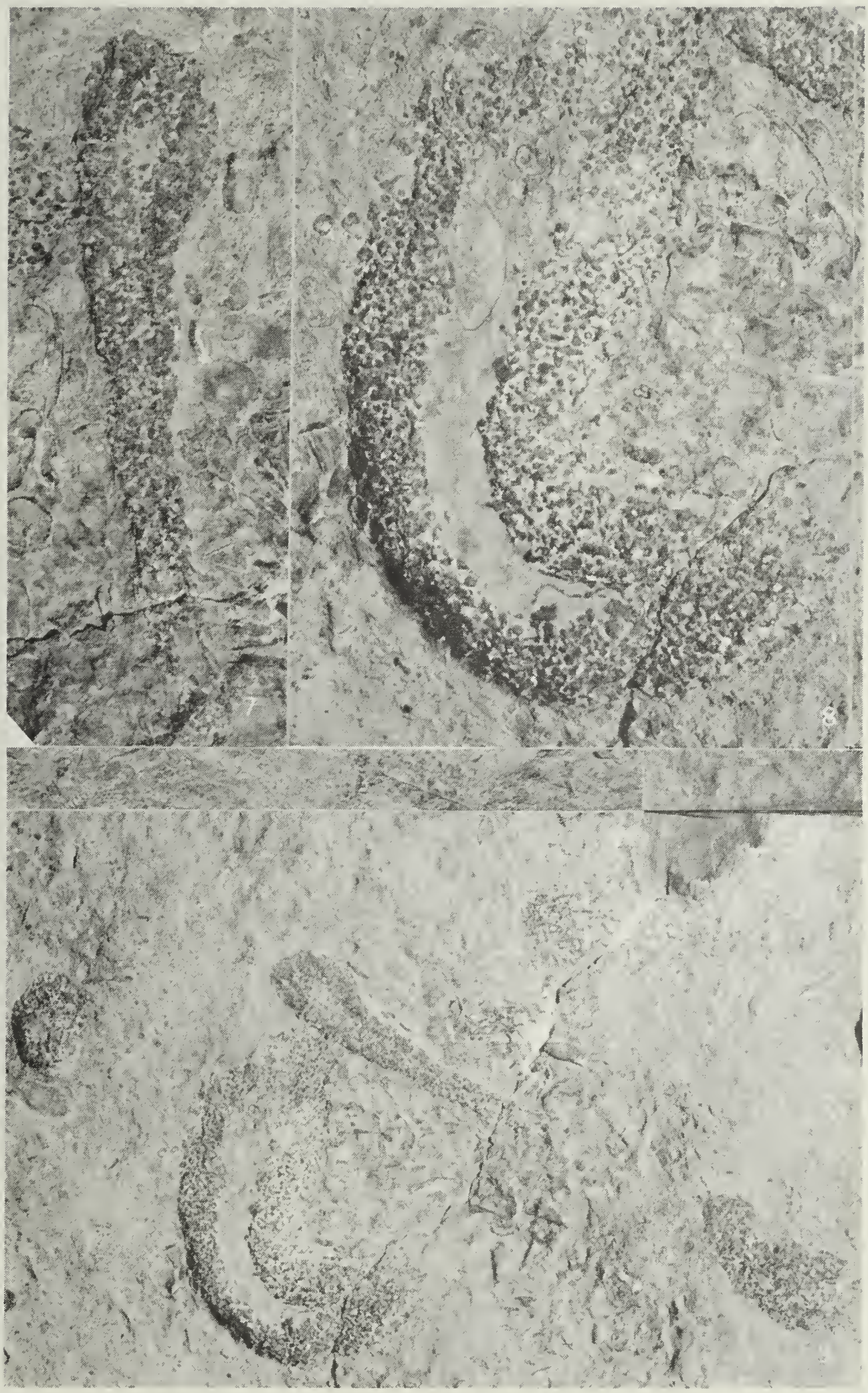

Figure 7. *Regispongia contorta,* lateral view of weathered and eroded specimen from Clore showing thick walls and long, narrow central cavity. Specimen slightly compressed, laterally. S.I.U.M. 4674 X2. Note also the elongate conical form.

Figure 8. *Regispongia contorta,* lateral view of weathered and eroded cylindrical contorted specimen from Clore showing thick walls and long, narrow central cavity. S.I.U.M. 4674 X2.

Figure 9. *Regispongia contorta,* top view showing alignment of specimens (Figures 5-8 above) parallel to bedding plane except for specimen on the left, lack of directional orientation, and clumped distribution of specimens from Clore. S.I.U.M. 4674 X2. Note also occurrence of conical and contorted forms side by side.

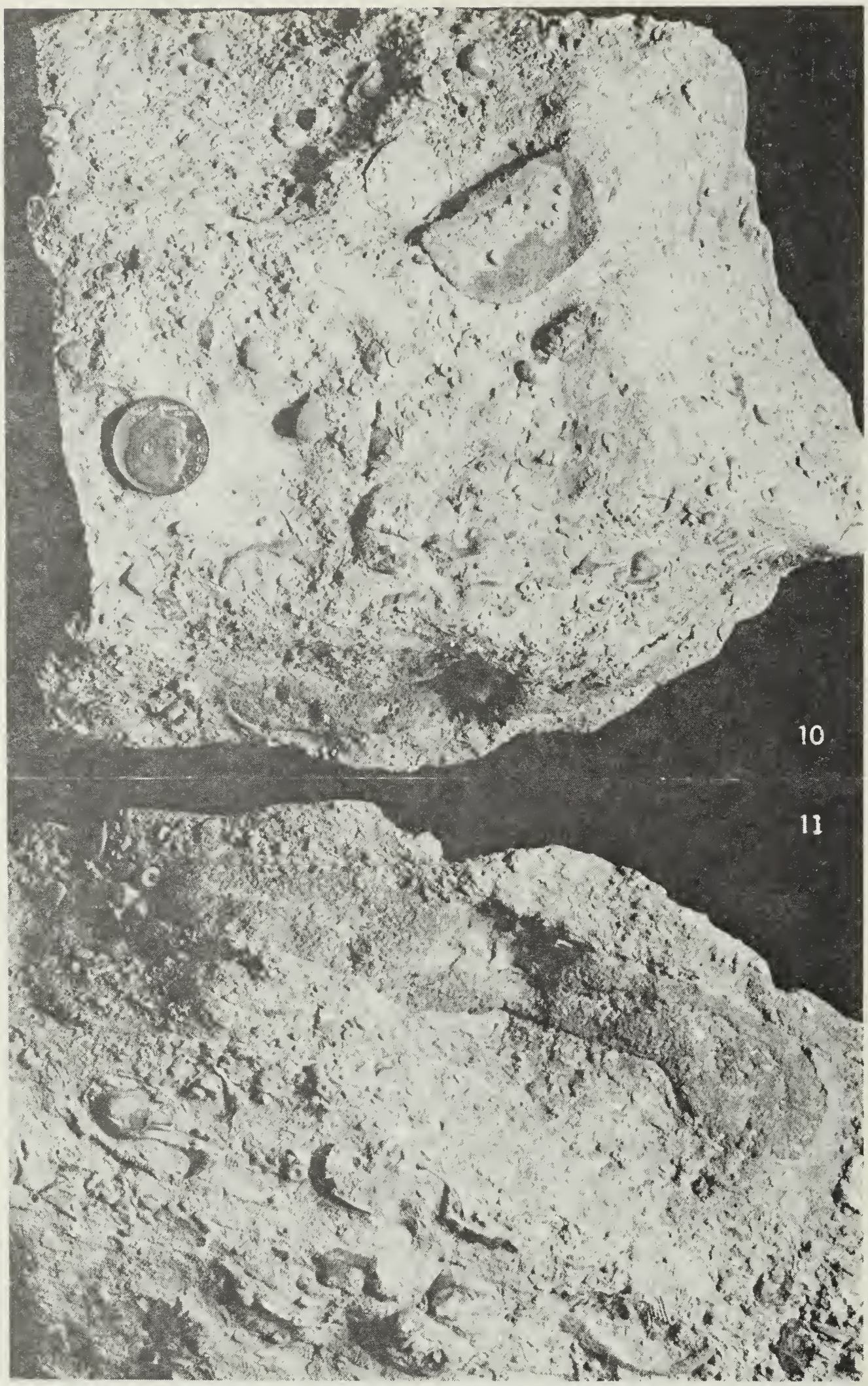

Figure 10. Top view of small slab showing much compressed *Regispongia contorta* specimen from Glen Dean parallel to and near lower margin X2/3. Note associated fauna: *Composita subquadrata* in lower center, *Agassizocrinus* plates in center and upper left, crinoid columnals, fenestrate bryozoan fragments in upper right, and ramose bryozoan fragments in lower left. S.I.U.M. 5485.

Figure 11. *Regispongia contorta,* lateral view of compressed, eroded and weathered specimen (enlargement of Figure 10) from Glen Dean X1.25. Note alignment parallel to sediment layers, *C. subquadrata* left center, crinoid columnals upper left, and fenestrate fragment lower right. S.I.U.M. 5485.

*S.I.U.M. refers to the Southern Illinois University Museum.

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PERCEPTIONS OF THE HABITAT EVALUATION PROCEDURES: A SURVEY OF WILDLIFE PROFESSIONALS

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ABSTRACT

1. This study surveyed baseline information on perceptions and attitudes of wildlife professionals towards the Habitat Evaluation Procedures (HEP). 2. Responses were solicited from all 50 states, 21 U.S. Fish and Wildlife Service Refuges and 10 U.S. Forest Service headquarters, with little difference in opinions between the groups towards HEP. 3. Perceived problems included a lack of data for non-game species (and thus for non-game models), extensive training, significant agency effort and resources used, and a lack of a link between model results and animal densities. 4. Perceived benefits included a general acceptance of the procedure, and a belief that results were accurate and reliable.

INTRODUCTION

The U.S. Fish and Wildlife Services' Habitat Evaluation Procedures (HEP) (USFWS 1980) is developing into an important tool in wildlife management. From its conceptual start as a simple method used to assess the effects of water development activities (Daniel and Lamaire 1974), HEP models have become widespread, not only in the original context of offering comparative ranking for alternative management strategies, but increasingly as a species habitat assessment tool. Other agencies have developed similar tools; the U.S. Forest Service (FS) has its unique

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habitat assessment model (Wildlife and Fish Habitat Relationship Program) as has the Corps of Engineers (Habitat Evaluation System). Although HEP is in general use, little is known about the attitudes towards HEP of those biologists which commonly utilize the system. It is the state fish and game biologists, the Fish and Wildlife Service managers, as well as other state and federal biologists who work closely with HEP and are most familiar with the strengths and weaknesses of the system. It was of interest, therefore, to assess the attitudes and perceptions of HEP users towards the most widespread system of wildlife habitat evaluation currently in use.

METHODS

A 10-point Likert-scale survey (1=strongly disagree, 10=strongly agree) was designed following principles outlined in Berdie et al. (1986). Questions were framed to determine perceptions of HEP in general, as well as assumptions upon which HEP rests (Table 1). In an attempt to survey a wide array of potential users of HEP, the survey was sent to heads of wildlife sections in all 50 states (STATES), 10 regional U.S. Forest Service (FS) headquarters, and 21 U.S. Fish and Wildlife Service (FWS) refuges. The survey consisted of 3 separate mailings, each approximately 5 weeks apart. A follow-up letter accompanied the second and third mailings. Due to duplication of responses from 2 STATES and 2 FS offices (different people responded to initial and follow-up questionnaires) and to an unsolicited response from a FWS employee, final possible survey responses totaled 84. Of these, 80 were returned, for an overall return rate of 95%. From these 80, 75 were usable (the rest declined to answer the survey, thus lowering functional return rate to 89%).

Initial sections of the survey consisted of several questions designed to determine group agency and agency use characteristics (cf. Appendix A). No attempt was made to specifically identify the 'rank' of the respondent, i.e., field biologist vs. agency administrator, and this may have introduced some variability into the results. However, voluntary responses, especially in the open comment section, suggested that many of the respondents were actively involved using HEP.

The remainder of the survey was a 10-point Likert scale. We tested mean overall response values against a theoretical non-committal response of 5.5 using a 2-tailed z-test, with an alpha equal to 0.05. If mean response was not significantly different, then results from the entire sample were viewed as neutral towards that question, resulting in no further analysis. If response values differed from 5.5, we used the Kruskal-Wallis ANOVA test to look for differences in response among the 3 groups (STATES, FWS, and FS). For those questions where ANOVA indicated a difference, t-tests were used to test for significance (alpha=0.05) between group means.

RESULTS AND DISCUSSION

Of total agency responses (n=75) (c.f. Appendix A), 50 (67%) were returned by state agencies, 15 (20%) were returned by FWS refuge biologists, and 10 (13%) by FS officials. Survey return rates varied by group with 49 of 50 states responding (98%), 18 of 22 refuges (82%), and 9 of 10 FS offices (90%).

Overall, 53 respondents (71%) said their organization used HEP in some form.

Use of HEP did not exclude use of some other formal method of habitat evaluation. Forty-nine of 75 respondents (65%) replied to the questions concerning additional methods; 27 (55%) did use another method, while 22 (44%) did not. Assuming no response meant no use of additional methods, then 26 of 75 (35%) responding agencies relied solely on HEP for evaluation needs. Of those which did not use HEP (n=22), 6 (27%) did use another formal method for evaluating wildlife habitat (type unknown). Thus, 16 of 75 respondents (21%) indicated that their agency did not use any formal method of evaluating wildlife habitat, including HEP.

Of those responding that their agency used HEP, twenty-one percent had been using HEP for the last 3 years, 47% for 4-7 years, and 33% for 8 years or more. Mean length of time an agency had been using HEP was 6.05 years (SD=2.75 years) with no significant differences among the 3 response groups.

The biologists as a group felt that HEP either was, or would be, a useful tool for their agency (Question 1 (Q.1), see Table 1 for all mean response values), with a significant difference among the 3 groups (P=0.0036). Although both STATES and the FWS indicated positive attitudes, the FWS was more so (P=0.0156). The FS and the STATES also differed (P=0.0148), with a perceptual difference between the FWS and the FS as well (P=0.0002). As evidence for the utility of HEP, 7 respondents indicated that their agency (e.g. Pennsylvania Game Commission) either used HEP to form a shorter version, or used its principles to create their own system. [Others in this group included the states of Arkansas, Colorado, Idaho, New York, and two Forest Service Regions (Alaska, Colorado).]

In a related question (Q.21), the biologists felt that use of HEP should be continued within their unit. Group response was neutral when asked if their agency expected to use HEP regularly in the future (Q.20).

The FWS conducts several training sessions annually to instruct biologists on proper use of HEP. We thus asked whether use of HEP required extensive formal training (Q.2). Overall, biologists felt this to be true. A related question asked whether a qualified wildlife biologist would provide a more accurate evaluation than HEP (Q.3). The total response was non-committal.

As HSI models are largely based upon data gathered from literature sources, we wished to determine whether biologists felt enough data were available for adequate model building. The entire group agreed that data were plentiful for game species (Q.18), but disagreed with the assertion that data were plentiful for non-game species (Q.19). There was strong agreement with a statement (Q.14) that model development to date did not adequately cover all groups of animals. Several individuals dissented with the validity of the models in general. One state biologist noted, "HSI models in many cases are nonsense, because they were developed with the attitude that the literature contains everything you need for such a model."

Published validations of HSI models have been scant (e.g., Lancia et al. 1982, Cole and Smith 1983, Bart et al. 1984). Published models generally rely upon use of species authorities, with little or no field validation trials (e.g., Allen 1982, Hamilton and Nelson 1984, Rorabaugh and Zwank 1983). The surveyed biologists strongly agreed that HEP had not been widely validated for accuracy of results (Q.7), yet they did feel that species authorities give accurate model validations (Q.13). A significant minority opinion was evident, however. One state biologist said, ". . . the HSI models . . . were never adequately field-tested and improved to the point where our agency has sufficient trust in the results of using HSI models for land use

planning." A FS respondent replied, "Just because species experts review models does not enhance the credibility to any great degree." All 3 groups strongly agreed that resource agencies should be involved with model validation efforts (Q.17). This seems to indicate that while species authorities may be appropriate for initial model development and verification, models are still seen as lacking validity until field tested.

Due to apparent controversy over perceived relationships between animal population densities and habitat suitability (e.g., Van Horne 1983), we queried the biologists to determine whether they felt a positive relationship to hold true (Q.9). The response was significantly positive although there was concern over lack of a definitive link between HSI model results and densities. Said one FS biologist, "Critical issues are . . . disclosure of expected relationships between HSI scores and animal density . . ." Another FS biologist felt that it would be difficult to "transcend the chasm between suitability index values and estimates of animal numbers." Whether or not HEP was designed to estimate animal numbers from the Habitat Suitability Index (it was not, 101 ESM, Sect. 4.4, USFWS 1980) seems irrelevant to some HEP users. Many seem to feel some link should exist and HEP was not much help in establishing a desired relationship in field situations.

We also asked if HSI models inaccurately reflected species-habitat relationships (Q.8). The group disagreed, feeling that HSI models were accurate. All 3 agency respondents felt HSI models adequately integrated habitat variables into one final evaluation result (Q.11).

Several questions sought general views on HEP. Overall response was neutral when asked if HEP was widely used by both federal and state agencies (Q.4). This was somewhat surprising. The impression given is that although a particular agency may use HEP regularly, they had no real notion if others did as well.

Group response was again neutral to the question of whether HEP provided a fast evaluation result (Q.5), however, the biologists agreed that HEP provided a reliable evaluation result (Q.6). There were significant differences among the 3 groups on this question ($P=0.0086$). The FWS more strongly agreed with this question than did the STATES ($P=0.0499$), who in turn agreed more strongly than did the FS ($P=0.0355$). Consequently, the FWS and the FS also differed ($P=0.0034$). It would seem that HEP is viewed as a reliable, though not necessarily fast, procedure.

The group was asked whether HEP models were easily used in field evaluations (Q.10), and the overall response did not differ from neutral. However, the biologists felt strongly that HEP had to be modified for local conditions (Q.16). The response was neutral when asked if extensive modifications were necessary (Q.12). Although HEP was designed to allow for local modifications of HSI models, most states operate under a limited time frame, thus forcing them either to use valuable time for modification or to make inadequate changes. Thus, the ability to modify HSI models for local conditions could prove to be a negative factor under some time constraints. We also wondered whether data necessary for implementation of HEP, even without model modification, were easily collected within agency time constraints (Q.15). The responding biologists felt not. A FS biologist noted, "Our problem is that HEP is too data intensive. We do not often have the time to collect the required data." Many STATES generally agreed with this view. Other respondents indicated that, while not a panacea, HEP was the best option currently

available. One state biologist remarked, "Although we have heard criticisms of HEP, we are generally pleased with the results of its use, and feel it is the best tool we have available to us at this time!"

SUMMARY

This survey served to evaluate initial perceptions and opinions from biologists who use the Habitat Evaluation Procedures (HEP). Likert-type surveys were sent to all 50 states, 21 U.S. Fish and Wildlife Service refuges, and 10 U.S. Forest Service regional headquarters. HEP has been accepted for use in many locations and under varying circumstances and is viewed as a valuable tool in wildlife and resource management. It is used by state and federal agencies alike and there appear to be few differences in opinion between the three surveyed groups about several aspects of HEP. Perceived problems identified through this survey include the need for extensive training, a lack of data for non-game species for constructing models, as well as a general lack of models for many animal groups. Species authority validation as an initial step was seen as acceptable, although field tests were seen as necessary, along with agency participation in the process. HEP was seen as taking significant effort and resources relative to agency time constraints, but was also seen to provide an accurate evaluation result. Biologists felt some definitive link between animal densities and habitat suitability needs to be established.

ACKNOWLEDGMENTS

We thank all of the state and federal biologists who took time to answer the questionnaire. We thank G. Feldhamer and T. Anthony for reviewing early versions of this manuscript, as well as two anonymous reviewers for their efforts. This study was supported by the Department of Zoology, Southern Illinois University, Carbondale.

LITERATURE CITED

Allen, A.W. 1982. Habitat suitability index models: Fox squirrel. FWS/OBS 82/10.18. U.S.D.I. Fish and Wildl. Serv. Washington, D.C. 11 pp.

Bart, J., D.R. Petit, and G. Linscombe. 1984. Field evaluation of two models developed following the Habitat Evaluation Procedures. Trans. N. Am. Wildl. Nat. Resourc. Conf. 49:489-499.

Berdie, D.R., J.F. Anderson, and M.A. Niebuhr. 1986. Questionnaire design and use. The Scarecrow Press, Inc., Metuchen, NJ. 330 pp.

Cole, C.A., and R.L. Smith. 1983. Habitat suitability indices for monitoring wildlife populations—An evaluation. Trans. N. Am. Wildl. Nat. Resourc. Conf. 48:367-375.

Daniel, C., and R. Lamaire. 1974. Evaluating effects of water resource developments on wildlife habitat. Wildl. Soc. Bull. 2(3):114-118.

Hamilton, K. and P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability index curves: White bass. Biol. Rep. 82(10.89). U.S.D.I. Fish and Wildl. Serv. Washington, D.C. 35 pp.

Lancia, R.A., S.D. Miller, D.A. Adams, and D.W. Hazel. 1982. Validating habitat quality assessment: An example. Trans. N. Am. Wildl. Nat. Resourc. Conf. 47:96-110.

Rorabaugh, J.C. and P.J. Zwank. 1983. Habitat suitability index models: Mottled duck. FWS/OBS 82/10.52. U.S.D.I. Fish and Wildl. Serv. Washington, D.C. 26 pp.

U.S. Fish and Wildlife Service. 1980. Habitat evaluation procedures. U.S. Fish and Wildl. Serv. 101-104 ESM, Div. Ecol. Serv., Washington, D.C.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47(4):893-901.

Table 1. Mean response values, on a 10-point Likert scale, by state fish and wildlife agencies (STATE), the U.S Fish and Wildlife Service (FWS), and the U.S. Forest Service (FS).

Question	Overall[a]	Sig.[b]	STATE	FWS	FS
1. HEP is or would be a useful tool for my agency.	6.97 2.19	*	6.96 2.20	8.45 1.13	5.22 1.92
2. Use of HEP requires extensive formal training.	6.64 2.35	*	7.04 2.38	5.55 1.15	6.00 2.67
3. A qualified wildlife biologist would provide a more accurate habitat evaluation than would HEP.	5.24 2.40		5.23 2.42	4.80 2.74	5.88 1.96
4. HEP is widely used in resource agencies (Federal and State) throughout the United States.	5.24 2.14		5.13 2.04	3.80 1.79	6.63 2.20
5. HEP does not provide a fast evaluation result.	5.87 2.84		6.13 2.83	5.25 2.71	5.00 3.12
6. HEP provides a reliable evaluation result.	6.68 2.29	*	6.71 2.28	8.13 1.81	5.22 1.99
7. HEP has been widely validated for accuracy of results.	3.54 2.17	*	3.75 2.31	3.83 2.23	2.38 0.92
8. HEP Habitat Suitability Index (HSI) models generally are not an accurate reflection of species-habitat relationships.	4.27 2.24	*	4.44 2.29	3.82 1.94	4.00 2.40
9. Wildlife population densities generally are directly related to habitat suitability.	7.23 2.39	*	7.32 2.40	7.64 1.98	6.20 2.82
10. HEP models are easily used in field evaluations.	6.03 2.25		5.91 2.34	6.44 2.13	6.25 2.05
11. HSI models adequately integrate habitat variables into one final result.	6.21 2.33	*	6.24 2.22	6.36 2.42	5.90 2.96
12. HEP requires extensive modification to make it a useful technique.	5.66 2.69		5.84 2.75	4.88 2.70	5.43 2.44
13. Use of recognized authorities on each species provides accurate HSI model validation.	6.23 2.47	*	5.96 2.58	7.20 1.99	6.50 2.27
14. Model development to date does not adequately cover all groups of animals.	8.25 1.99	*	8.20 2.08	8.00 2.11	9.00 1.00
15. Data necessary to implement HEP are easily collected within time constraints of my agency.	4.36 2.42	*	4.30 2.40	4.44 2.46	4.50 2.73
16. HEP models must often be modified to satisfy local conditions.	8.27 1.84	*	8.14 2.09	8.13 0.99	9.00 0.82

Table 1. (Continued)

Question	Overall[a]	Sig.[b]	STATE	FWS	FS
17. Resource agencies should be involved with validating HEP models.	8.42 1.79	*	8.47 1.66	8.58 1.44	8.00 2.67
18. Data on habitat relationships are plentiful for game species.	6.56 2.41	*	6.57 2.39	7.45 1.13	5.50 3.21
19. Data on habitat relationships are plentiful for non-game species.	3.16 1.90	*	3.28 1.91	3.25 1.86	2.50 1.96
20. My agency expects to use HEP on a regular basis for the foreseeable future.	5.05 3.04		5.05 3.12	6.09 2.91	3.78 2.54
21. Use of the Habitat Evaluation Procedures should be discontinued in my agency.	2.75 2.31	*	2.85 2.49	2.80 2.15	2.00 1.15

[a]Values arranged as mean (top) and standard deviation (bottom).
[b]Indicates a significant difference between overall mean and 5.5 (neutral).

Appendix A. Questions asked of potential Habitat Evaluation Procedures (HEP) users to determine group affiliation and agency characteristics.

1. What resource agency do you represent? (State or Federal)
   (Response as % of survey mailed): FWS 71 FS 90 STATE 98

2. Does your agency use the U.S. Fish and Wildlife Services' Habitat Evaluation Procedures (HEP) in any form?
   (Respondents [n = 75]: YES = 53 NO = 22)

3. Does your agency use any formal standardized methods for evaluation of wildlife habitat quality? If so, what method is used?
   (Respondents to initial question: YES = 59 NO = 16)

4. How long has your agency been using HEP?
   (last 3 years: 11 4-7 years: 25 >8 years: 17)

5. Has your agency ever used any other standardized evaluation methods in conjunction with HEP or by itself? If so, which methods have been used?
   (Respondents to initial question: YES = 27 NO = 22 NA = 26)

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OCHETOSOMATID DIGENEANS FROM ILLINOIS SNAKES

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ABSTRACT

Digeneans extracted from the oral cavity of snakes captured in southern Illinois between June 1986 and August 1988 included *Ochetosoma elongatum* from *Heterodon platyrhinos*, *O. kansense* from *Lampropeltis getulus* and *O. ellipticum* from *Nerodia erythrogaster*, *N. rhombifera* and *Coluber constrictor*. *Nerodia erythrogaster*, *N. rhombifera* and *C. constrictor* represent new host records for *O. ellipticum*.

INTRODUCTION

Few reports are available on the Digenea, and in particular the ochetosomatid Digenea, of reptiles in Illinois. Dyer (1970) reported *Ochetosoma elongatum* (Pratt, 1903) in the lungs of the eastern hognose snake, *Heterodon platyrhinos* (Latreille) from Williamson County, *Ochetosoma kansense* (Crow, 1913) in the mouth of the gray rat snake, *Elaphe obsoleta spiloides* (Duméril, Bibron and Duméril) and the esophagus of *Lampropeltis* sp. also from Williamson County, and *Ochetosoma ellipticum* (Pratt, 1903) in the mouth of *H. platyrhinos* from Jackson County. Later, Dyer and McNair (1974) reported *O. elongatum* in the mouth, esophagus and stomach of *H. platyrhinos* and *O. kansense* in the mouth of the common kingsnake, *Lampropeltis getulus* (Linnaeus) from Jackson County. The present report adds to our knowledge on the spectrum of taxa of snakes in Illinois which serve as definitive hosts for ochetosomatid digeneans.

MATERIALS AND METHODS

Snakes were captured in Johnson and Jackson counties, southern Illinois between June 1986 and August 1988. The oral cavity of all snakes was examined

within two hours of capture for the presence of parasites. Digeneans were removed with a cotton swab saturated with tap water, and then transferred to a container of tap water where egg release was observed. After all or most of the eggs were released from the uterus, each digenean was transferred to a slide, and a crystal of urethane added to the water to induce relaxation. A coverslip was then added and the specimens studied alive. Later, the specimens were fixed in AFA (alcohol-formalin-acetic acid), stained with Harris' hematoxylin, dehydrated, cleared in beechwood creosote and mounted in Canada balsam. Voucher specimens have been deposited in the United States National Museum (USNM) Helminthological Collection, U.S. Department of Agriculture, Bethesda, Maryland. All measurements are in millimeters. Numbers in parentheses following the ranges are averages.

RESULTS AND DISCUSSION

Ochetosoma elongatum (Pratt, 1903)

Synonyms: *Renifer elongatus* Pratt, 1903; *Lechriorchis validus* Nicoll, 1911; *Lechriorchis inermis* Lebour, 1913; *Lechriorchis abduscens* Byrd and Denton, 1938; *Renifer magnus* Byrd and Denton, 1938; *Neorenifer heterodontis* Byrd and Denton, 1938; *Neorenifer drymarchon* Byrd and Denton, 1938; *Renifer grandispinus* (and *R. longispinus, lapsus calami*) Caballero, 1938.

Observations are based on 20 sexually mature specimens from the mouth of two *Heterodon platyrhinos*. Several minor variations exist between the present material and that originally described (Pratt, 1903). The body length recorded here was 2.80-4.26 (3.62) as compared to 3.00, and the body width was 0.71-1.10 (0.78) as compared to 0.68. Oral sucker measurements ranged from 0.29-0.37 (0.32) by 0.27-0.36 (0.34) as compared to 0.32 by 0.33 and acetabular measurements ranged from 0.43-0.51 (0.47) by 0.41-0.55 (0.48) as compared to 0.40 by 0.36. Pharyngeal measurements ranged from 0.11-0.17 (0.15) by 0.13-0.16 (0.14). The original author listed the pharynx as being 0.06 long (Pratt, 1903).

Testes size was somewhat different, 0.45-0.65 (0.47) long by 0.24-0.31 (0.27) wide as compared to 0.32 long by 0.16 wide. Cirrus sac measurements ranged from 0.62-1.15 (0.91) long by 0.20-0.27 (0.19) wide as compared to 0.70 by 0.16 given originally.

Ovaries ranged from 0.09-0.20 (0.18) by 0.11-0.16 (0.13) contrasted with a length of 0.16 as stated originally. Egg size was reported as 0.035 long by 0.02 wide; ranges of 0.037-0.042 (0.034) by 0.015-0.022 (0.016) were recorded for the eggs in this study.

Ochetosoma elongatum has been reported previously from several snake hosts including *Coluber constrictor, Drymarchon corais couperi, Heterodon platyrhinos* and *Lampropeltis getulus*. Voucher specimens were deposited in the USNM Helminthological Collection (No. 80440).

Ochetosoma ellipticum (Pratt, 1903)

Synonyms: *Renifer ellipticus* Pratt, 1903; *Ochetosoma formosum* Nicoll, 1911; *Renifer septicus* MacCallum, 1921; *Renifer ophiboli* MacCallum, 1921; *Ochetosoma adenodermis* Pérez Vigueras, 1942.

Observations of *Ochetosoma ellipticum* from Illinois snakes were based on 28 specimens from the mouth of one *Nerodia rhombifera*, two *N. erythrogaster*, and one *Coluber constrictor*. The material from this study was considerably smaller in every respect than the original material described by Pratt (1903). The maximum length given originally was 4.2 mm, while the maximum in the present study was 3.2 mm. The reproductive organs were smaller in the present study than in the published data (Pratt, 1903). The relative position of the testes, ovary and vitellaria leave no doubt that the present material is conspecific with *O. ellipticum*.

Ochetosoma ellipticum has been reported from *Heterodon platyrhinos, Lampropeltis getulus holbrooki, Xenodon colubrinus,* and *Erythrolamprus aesculapii.*

Nerodia rhombifera, N. erythrogaster and *Coluber constrictor* represent new host records for this parasite. Voucher specimens were deposited in the USNM Helminthological Collection (No. 80439).

Ochetosoma kansense (Crow, 1913)

Synonyms: *Renifer kansensis* Crow, 1913; *Neorenifer georgianus* Byrd and Denton, 1938; *Neorenifer grandularis* Byrd and Denton, 1938; *Neorenifer serpentis* Schmidt and Hubbard, 1940; *Neorenifer elaphis* Parker, 1941; *Neorenifer crotali* Self, 1945 and *Neochetosoma crotali* (Self, 1945) Caballero, 1949; *Renifer floridanus* Kegan, 1947.

Observations of *Ochetosoma kansense* were based on 25 specimens from the mouth of two *Lampropeltis getulus*.

The present material agrees with the description of this species as reported by Dubois and Mahon (1959). It has been reported previously from *Agkistrodon contortrix, A. piscivorus, Diadophis punctatus stictogenys, Elaphe obsoleta spiloides, Heterodon platyrhinos* and *Lampropeltis getulus*. Voucher specimens were deposited in the USNM Helminthological Collection (No. 80441).

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LITERATURE CITED

Dubois, G. and J. Mahon. 1959. Etude de quelques trématodes nord-americains (avec note sur la position systématique de *Parorchis* Nicoll, 1907) suivie d'une revision des genres *Galactosomum* Looss 1899 et *Ochetosoma* Braun 1901. Bull. Soc. Neuchatel Sc. Nat. 82: 191-229.

Dyer, W.G. 1970. Ochetosomatid trematodes from snakes in North Dakota and Illinois. Proc. Helminthol. Soc. Wash. 37: 229.

Dyer, W.G. and D.M. McNair. 1974. Ochetosomatid flukes of colubrid snakes from Illinois and Central America. Trans. Ill. State Acad. Sci. 67: 463-464.

Pratt, H.S. 1903. Descriptions of four distomes. Mark Anniversary Volume, New York. 25-39.

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SPAWNING IN THE EASTERN SAND DARTER, AMMOCRYPTA PELLUCIDA (PISCES: PERCIDAE), WITH COMMENTS ON THE PHYLOGENY OF AMMOCRYPTA AND RELATED TAXA

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ABSTRACT

The spawning behavior of *Ammocrypta pellucida* was studied in order to provide a better understanding of the life history of *Ammocrypta* and the evolution of spawning behaviors in darters. In this study *A. pellucida* spawned in aquaria in 1987 and 1988. Spawning was not observed in 1987 but eggs and larvae were recovered. In 1988 twelve spawning episodes were observed and eggs were recovered. Spawning occurred in pairs, or less frequently with two males and one female. Eggs were buried singly in the sand.

INTRODUCTION

Spawning has not been described for any of the seven species of *Ammocrypta*, although spawning descriptions have been published for 73 species of *Etheostoma* and *Percina* (Page and Simon 1988). A study of the spawning behavior of *Ammocrypta pellucida* was conducted in order to better understand the evolution of breeding behaviors in darters, and to provide valuable life history information for this species.

MATERIAL AND METHODS

Five collections of *A. pellucida* were made from 2 June - 29 July 1987 in the Tippecanoe River at Talma, Fulton County, Indiana. Seine hauls were made in all

available habitats in a 0.4 km section of the river. The number, sex, and reproductive state of the sand darters were noted, along with the physical characteristics of the habitat where they were taken.

Live specimens of both sexes of *A. pellucida* were brought back to the Illinois Natural History Survey for aquarium observations. From 2-28 June a total of 11 *A. pellucida* were placed in a 151-liter tank. Water was 30 cm deep, and a filter placed on the side of the tank generated visible current. The substrate ranged from medium-sized gravel to fine sand. The average substrate depth was 5 cm. Mussel shells, plants, and large rocks were placed in the tank as spawning substrate choices. In December 1987 the fish were transferred to a 37.8-liter tank with a bubble filter. The substrate and spawning choices were the same as before.

RESULTS AND DISCUSSION

In the Tippecanoe River, sand darters were most abundant in swiftly flowing water approximately 30 cm deep, over a substrate of approximately 80% sand and 20% gravel. These areas were usually the deepest, swiftest runs. During intensive sampling on 26 July 23 male and 4 female *A. pellucida* were captured, suggesting that males had congregated in the area sampled, or that males outnumber females in the population. During our sampling period, males and females could be distinguished by the presence of dark pigmentation on the pelvic fins of the males and the distended abdomens of the females. Water temperatures during field observations ranged from 17-26C.

In 1987, spawning was not observed but eggs and larvae were found in the tank. Eggs were first found on 29 June 1987. Sixty-six eggs were found buried in the mixed sand and gravel substrate and were dispersed over an area 10 x 16 cm. Fertilized eggs were translucent, spherical, and slightly adhesive. Mean egg diameter was 1.4 mm (range 1.1-1.7 mm, n=24, SD=0.15). The tank was searched daily from 29 June to late July, 1987. Eggs and larvae were found from 29 June to 16 July 1987 at approximately 4-5 day intervals.

Spawning was first observed in *A. pellucida* on 7 April 1988 at 2100 hr. One female and four males were on the substrate surface. The males pursued the female around the tank, often resting their pelvic fins and chin on her back. When the female was ready to spawn, she moved to a sand and gravel area in the corner of the tank and sat motionless. In 9 of 12 spawning episodes she was mounted by a male who positioned himself directly on top of her. Egg deposition occurred when the pair vibrated, burying their tails and caudal peduncles in the substrate. In the remaining three spawning episodes witnessed, the pair was joined by a second male who positioned himself on one side of the female and vibrated with the pair. Eggs were buried singly in the substrate.

Spawning lasted from 7 April to about 10 June 1988 and occurred both day and night, at water temperatures of 20.5-23C. It is probable that a female spawns many times during the season. During the breeding season males develop dark pigmentation on the first three to four outer rays of the pelvic fins and small tubercles on the ventral surface of the first few outer pelvic rays. It is apparent by their positions and the posture of the male and female during spawning, that these tubercles act to hold or stimulate the female during spawning.

Given the burying lifestyle of this species, its spawning strategy of egg burying is not surprising. The spawning substrates used by darters with other spawning

methods, such as plants, boulders, and flat rocks, often are unavailable in the immediate environment of sand darters, and spawning migrations are rare in darters (Page 1985). It is likely that egg survivorship is high in the well-oxygenated substrate where *Ammocrypta* live and bury eggs. This strategy is similar to that of many other darters in the genera *Percina* and *Etheostoma*, such as *P. carprodes*, *E. caeruleum*, and *E. stigmaeum* (Winn 1958), which also bury their eggs in well-oxygenated substrate (Page 1985).

The occurrence in *A. Pellucida* of 'sneaker males', or males which attempt to join a spawning pair also is not surprising since it has been reported for other darters with similar spawning strategies, for example *E. caeruleum* (Reeves 1907), *Percina pantherina* (James, et al. 1988) and *Etheostoma rufilineatum* (Stiles 1988). Sneaking will most likely be found to be common as more detailed work is done on spawning strategies in darters.

The genus *Ammocrypta* was regarded as a specialized derivative of *Percina* by Bailey and Gosline (1955), but recent studies suggest a common origin for *Etheostoma* and *Ammocrypta* (Page and Whitt 1973a, 1973b). Page and Whitt (1973a) suggested that *E.* (*Vaillantia*) *chlorosomum* is the sister taxon to *Ammocrypta*, and Page (1985) proposed the phylogenetic relationships among species of the subgenera *Boleosoma*, *loa*, *Vaillantia*, and *Doration* shown in Fig. 1A. Members of *Doration* are egg buriers, of *Vaillantia* are egg attachers, and of *loa* attach their eggs in clusters similarly to *Boleosoma*, which are egg clusterers and have parental care (Page 1985). Simons (1988) has proposed, based on osteological evidence, that *E.* (*loa*) *vitreum* is the sister taxon to *Ammocrypta*, with *Boleosoma* and *Vaillantia* as the sisters to this clade (Fig. 1B).

The hypothesis Fig. 1A, of Page (1985) parallels the progression in complexity of reproductive behaviors from egg burying in *Doration*, egg attaching in *Vaillantia*, attaching in clusters in *loa*, to egg clustering and parental care in *Boleosoma*. If *Ammocrypta* is added as the sister taxon to *Vaillantia* (Page and Whitt 1973a), egg burying is a reversal to the primitive state in *Ammocrypta*, or egg attaching arose independently in *Vaillantia* and *loa*/*Boleosoma*. The hypothesis of Simons (1988) with *Ammocrypta* as the sister taxon to *loa* (Fig. 1B), requires either independent origins for egg attaching/clustering in *Vaillantia*, *Boleosoma*, and *loa* (if *Doration* or any other egg-burying darters are considered to be the sister group), or a reversal to the primitive egg-burying behavior in *Ammocrypta*, with egg attaching first appearing in *Vaillantia*. More detailed genetic and osteological work will aid in determining the best hypothesis of relationships among these taxa.

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LITERATURE CITED

Bailey, R.M. and W.A. Gosline. 1955. Variation and systematic significance of vertebral counts in the American fishes of the Family Percidae. Misc. Publ. Mus. Zool. Univ. Mich. 93. 44 p.

James, P.W., S.C. Leon, and O.E. Maughan. 1988. Life history and habitat analysis of the leopard darter, *Percina pantherina*. Abstract, 68th Annual Meeting of the American Society of Ichthyologists and Herpetologists, Ann Arbor, Michigan.

Page, L.M. 1985. Evolution of reproductive behaviors in percid fishes. Bull. Ill. Nat. Hist. Surv. 33(3):275-295.

Page, L.M. and T.P. Simon. 1988. Observations on the reproductive behavior and eggs of four species of darters, with comments on *Etheostoma tippecanoe* and *E. camurum*. Trans. Ill. State Acad. Sci. 81:205-210.

Page, L.M. and G.S. Whitt. 1973a. Lactate dehydrogenase isozymes, malate dehydrogenase isozymes and tetrazoloim oxidase mobilities of darters (Etheostomatini). Comp. Biochem. Physiol. 44B:611-623.

Page, L.M. and G.S. Whitt. 1973b. Lactate dehydrogenase isozymes of darters and the inclusiveness of the genus *Percina*. Ill. Nat. Hist. Surv. Biol. Notes 82. 7 p.

Reeves, C.D. 1907. The breeding habits of the rainbow darter (*Etheostoma caeruleum* Storer), a study in sexual selection. Biol. Bull. (Woods Hole) 14:35-59.

Simons, A.M. 1988. The phylogenetic relationships of the genus *Ammocrypta* (Percidae). Abstract, 68th Annual Meeting of the American Society of Ichthyologists and Herpetologists, Ann Arbor, Michigan.

Stiles, R.A. 1988. Female mimicry by males of *Etheostoma rufilineatum*. Abstract, 68th Annual Meeting of the Society of Ichthyologists and Herpetologists, Ann Arbor, Michigan.

Winn, H.E. 1958. Observations on the reproductive habits of darters (Pisces: Percidae). Am. Midl. Nat. 59(1): 190-212.

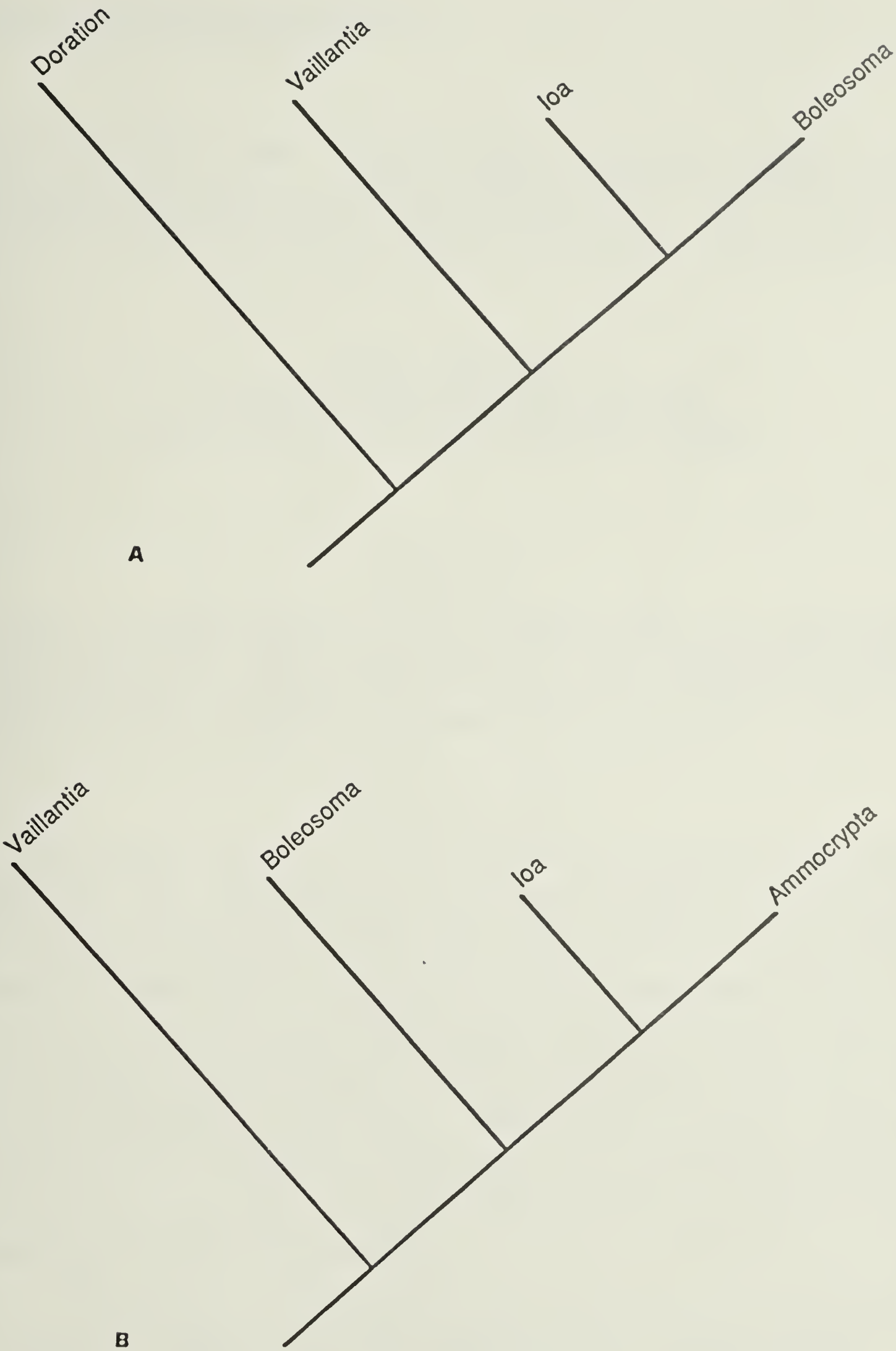

Figure 1. A. Hypothesized phylogenetic relationships of *Doration, Vaillantia, loa* and *Boleosoma* from Page (1985). B. Hypothesized relationships of *Vaillantia, Boleosoma, loa* and *Ammocrypta* from Simons (1988).

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EFFECTS OF THE 1988 DROUGHT ON BOBWHITES IN SOUTHERN ILLINOIS

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ABSTRACT

Severe drought conditions occurred throughout much of the United States during summer 1988. Using a 39-year record of bobwhite population and weather data as a baseline, it appeared that the drought adversely affected bobwhite reproduction and subsequent fall abundance in southern Illinois.

INTRODUCTION

The Northern bobwhite's (*Colinus virginianus*) geographic range includes virtually the entire United States east of the Rocky Mountains and south of the mixed coniferous-hardwood forest (Rosene 1969). Populations are most stable in the Southeast where annual rainfall >125cm and snowcover is rare; elsewhere, short-term fluctuations are often related to weather perturbations. In the Southwest, abundance is primarily determined by annual and seasonal precipitation (Jackson 1962, Lehmann 1984). In the Midwest, bobwhites are most affected by winter weather, especially duration of snowcover (Kabat and Thompson 1963, Stanford 1972, Roseberry and Klimstra 1984). Summer conditions, especially drought, can also be occasionally harmful (Stanford 1972, Roseberry and Klimstra 1984). The summers of 1930, 1934, 1936, 1952 and 1953 reportedly affected Midwestern bobwhite populations (Leopold and Ball 1931, Errington 1935, Bennitt and Nagel 1937, Wade 1938, Stanford 1953).

In 1988, a severe drought occurred over much of the United States. The objective of this paper is to describe the apparent effects of this climatological phenomenon on bobwhite reproduction and abundance in southern Illinois.

METHODS

Bobwhite population data were obtained as part of a separate, long-term study conducted by the Cooperative Wildlife Research Laboratory, SIU-C. From 1950

through 1988, a select group of quail hunters throughout the southern 34 counties of Illinois submitted an average 3,700 wings annually from harvested birds along with sex, date, and county where taken. Kill/effort data and subjective opinions regarding relative abundance were also obtained from 100-150 cooperators annually. Age of harvested quail was determined by appearance and molt of primary and covert wing feathers (Leopold 1939, Haugen 1957, Petrides and Nestler 1952). Hatching chronology was determined by backdating estimated age from date of kill. Young:adult ratios served as a measure of reproductive success the previous breeding season (Roseberry 1974), while hunter opinions and kill/effort data were used to assess relative population abundance.

Weather data (maximum and minimum daily temperature and precipitation) were obtained from approximately 30 weather-recording stations throughout southern Illinois for the period 1950-1988 (U.S. Dept. Commerce 1950-1988) and the years 1930, 1934, and 1936 (U.S. Dept. Agriculture 1930, 1934, 1936). Total precipitation, average daily temperature, and maximum daily temperature were computed for the following segments of the bobwhite's reproductive season: April (prenesting); 21 April-18 August (egg laying); 1 May-19 July (peak egg laying); 10 June-28 August (hatching); 20 June-18 August (peak hatching).

FINDINGS

1988 Drought

Cumulative precipitation for the 3-month period January-March, 1988 was above normal throughout southern Illinois. The months of April, May, and June, however, were extremely dry. Accumulated precipitation deficit for the 3-month period ending 30 June was approximately 60% (7.4″ deficit from 12.3″ normal). The drought was partially broken the 2nd week in July and precipitation for the month was slightly above average for the area as a whole. As is common in summer, however, there was considerable local variation. For example, Carmi in White County received 10.9″ of rainfall while Dixon Springs in Pope County recorded only 1.5″. Generally dry conditions returned in August with a monthly precipitation deficit of about 45% over most of the area.

To better assess the relative severity of the 1988 drought, precipitation during critical periods of the bobwhite's reproductive season was compared with the 1950-1987 mean and with historic drought years (U.S. Dept. Agriculture 1930, 1934, 1936). The 1988 egg laying season (21 April-18 August) was the driest recorded during the 39-year study (9.0″ rainfall or 56% of normal), while the hatching season (10 June-28 August) was the 7th driest (7.6″ rainfall or 77% of normal). Neither season was as dry as comparable periods in 1930 or 1936 which represent the 2 most severe summer droughts in recorded Illinois weather history (1878-1988). The 1988 egg-laying season was, however, drier than comparable periods in 1934, 1952, and 1953, while the hatching season was drier than 1934 and similar to 1952 (Fig. 1).

Temperatures during summer 1988 were above normal, but did not deviate relatively as much as did precipitation. Mean maximum daily temperatures during the egg-laying season (87.0°F) were the highest recorded during the 39-year period and were 3.4°F above the long-term mean. Temperatures during the hatching season (91.3°F) were also above normal (88.5°F) but were only the 7th highest recorded since 1950. Temperatures during the summer of 1988 were similar to those

of 1952 and 1953 but considerably below those recorded in the 1930s. The mean number of days with maximum temperatures ≥100°F per station in 1988 (9.1) was similar to 1952 and 1953 (7.3-7.4) but much less than 1930 (22.6), 1934 (18.5), or 1936 (36.0).

Bobwhite Population Parameters

The 1988 juvenile:adult harvest ratio of 3.45 was 32.5% below the 1950-1987 mean and the 3rd (tie) lowest recorded for that period. The proportion of males among juveniles was slightly higher than the long-term mean (51.2 vs 50.3%) while representation of males among adults was below average (57.2 vs 60.2%). Hatching chronology, as measured by an index of birds hatched after 29 July, was normal.

Relative abundance of bobwhites in southern Illinois was lower than expected during autumn 1988. Various predictive models based on previous winter conditions, spring call counts, and cyclic tendencies suggested a fall 1988 quail density similar to the previous year (unpubl. data, CWRL); Illinois Department of Conservation predictions, based primarily on early-summer male whistling counts, were for an approximate 12% increase (Jack Ellis, pers. comm). In 1988, 103 hunters reported harvesting an average 3.36 birds/trip during 2,024 outings. This kill/effort index was down 12.3% from 1987 and was 9.7% below the long-term mean. Subjective hunter opinions regarding comparative abundance in 1988 vs 1987 indicated an even greater population decline. The frequency of response from 115 hunters was: smaller, 72%; same, 17%; and larger, 11%. A computed index of abundance based on these opinions was the 5th lowest recorded since the study was initiated. Many hunters noted that individual coveys tended to be numerically smaller than average. Separate field research by the author in Williamson County confirmed this observation.

DISCUSSION

A general consensus among quail biologists is that cool-moist summers are more conducive to good bobwhite reproduction than are hot-dry summers (Rosene 1969, Roseberry and Klimstra 1984). Positive correlations between summer precipitation and reproductive output have been reported in Florida (Murray 1958), Alabama (Speake and Haugen 1960), Kentucky (Durell 1957), Louisiana (Reid and Goodrum 1960), Texas (Kiel 1976), and Kansas (Robinson 1957). No statistical relationship was evident, however, between summer weather and recruitment rates during a 26-year study of a local southern Illinois population (Roseberry and Klimstra 1984). Similarly, no correlation ($P < 0.05$) was found between various measures of summer precipitation and temperature and either juvenile:adult ratios or indices of abundance for the 1950-1988 regional data set. Errington (1946) likewise could not relate bobwhite recruitment rates to summer weather during a 15-year study in Wisconsin. Lack of statistical correlation could be due to a) the bobwhite's extended nesting season and propensity for renesting following failure, b) inadequate measurement of critical weather parameters and population responses, c) and inherent tolerance of the species to variable weather (Roseberry and Klimstra 1984). In addition, the impact of winter weather in the Midwest may tend to mask more subtle summer effects.

Nevertheless, it appears that extreme drought conditions can and do periodically affect bobwhite reproduction and abundance. According to Leopold and Ball

(1931), the 1930 drought (combined with a severe previous winter) reduced quail populations in Illinois and elsewhere in the Midwest to <50% of normal. The 1934 drought was also reported to have depressed quail populations in Missouri (Bennitt and Nagel 1937) and Iowa (Errington 1935). Wade (1938) noted that Wisconsin quail numbers were down as much as 80% following the 1936 drought (also preceded by a severe winter). Stanford (1953) reported that Missouri bobwhites were adversely affected by consecutive droughts in 1952 and 1953.

Bobwhite recruitment in southern Illinois during 1988, as measured by subsequent juvenile:adult harvest ratio, was >32% below normal and the 3rd lowest recorded since 1950. And, while hunter success was not greatly reduced, a large majority (72%) of responding hunters thought the 1988 population was lower than the previous year. In the absence of concurrent nesting studies, cause and effect relationships with the drought cannot be established with absolute certainty. I believe, however, that the poor reproduction, small coveys, and lower-than-predicted population levels in 1988 were directly attributable to the drought. Overall impact was perhaps not as great as expected given the relative severity of conditions because a) the previous mild winter left breeding populations in good shape, numerically and physically; b) July rains provided some relief; and c) temperatures, while above-average, were not extreme when compared to historic drought years.

The causative mechanisms and reproductive components involved in bobwhite-drought interactions are not fully understood. In the semi-arid Southwest, there is often complete cessation of laying during such periods (Lehmann 1984, Guthery et al. 1988). Early termination of nesting has also been reported in Missouri (Stanford 1972) and Illinois (Klimstra and Roseberry 1975). This is substantiated by a negative correlation ($r = -0.45$; $P < 0.01$) between maximum daily summer temperatures and the relative proportion of late-hatched birds over a 35-year period in southern Illinois. Hot, dry conditions may also increase nest abandonment (Stoddard 1931, Stanford 1972, Klimstra and Roseberry 1975), reduce hatchability of eggs (Stoddard 1931, Murray 1958, Rosene 1969, Stanford 1972), lower chick survival (Haugen 1955, Reid and Goodrum 1960), and possibly increase mortality of adult hens (Stanford 1953, 1972). Occurrence of small coveys in the autumn 1988 population is consistent with poor hatchability of eggs and/or reduced chick survival. Below-normal representation of males in the adult segment would not indicate unusually high mortality of adult hens. Normal representation of late-hatched birds in the 1988 sample seemed contradictory to the above-noted tendency for early-termination of nesting during hot-dry summers. Apparently, both late *and* early hatches were reduced so that chronology appeared normal.

Summer weather can act directly on individual bobwhites or indirectly through their vegetative and insect food supplies. An obvious direct effect would be reduction in surface water. Guthery (1987), however, believed that in non-arid regions, bobwhites do not normally require free water, subsisting instead on metabolic and preformed water. Other direct effects include reduced hatchability of eggs due to high ground temperatures and/or low humidity. More speculative is Cain and Lien's (1985) theory that drought-related environmental conditions may elicit a non-specific stress response that would inhibit reproduction through pituitary-adrenal stimulation. Several authors have noted the potentially detrimental consequences of a reduction in quantity and quality of food (both vegetative and

insect) and cover due to severe drought (Stoddard 1931, Nestler 1946, Haugen 1955, Murray 1958, Reid and Goodrum 1960). Of possible significance too are Leopold et al's. (1976) finding that in dry years, desert vegetation produced increased quantities of phytoestrogens that inhibited reproduction in California quail (*Lophortyx californicus*); or Cain et al's. (1982) suggestion that drought-induced phosphorous deficiencies might contribute to poor reproduction.

Although the 1988 drought may not have resulted from excess carbon dioxide in the atmosphere, i.e., the "greenhouse effect" (Changnon 1988), uncertainty exists as to whether we are experiencing, or are about to experience, a global warming trend (Kerr 1988, 1989). Regardless, the summer of 1988 should remind us that climatic change would almost certainly affect the distribution and abundance of native wildlife. The short- and long-term effects, however, would be difficult to predict. A warming trend in the midwest would probably initially favor bobwhites with milder winters; but hotter, drier summers could ultimately be detrimental. Perhaps the greatest impact on wildlife would come from land use and agricultural changes resulting from altered climatological patterns.

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LITERATURE CITED

Bennitt, R., and W.O. Nagel. 1937. A survey of the resident game and furbearers of Missouri. Univ. Mo. Studies 12(2):1-215.

Cain, J.R., S.L. Beasom, L.O. Rowland, and L.D. Rowe. 1982. The effects of varying dietary phosphorus on breeding bobwhites. J. Wildl. Manage. 46(4):1061-1065.

Cain, J.R., and R.J. Lien. 1985. A model for drought inhibition of bobwhite quail (*Colinus virginianus*) reproductive systems. Comp. Biochem. Physiol. 82A(4):925-930.

Changnon, S. 1988. Drought and the greenhouse effect. The Nature of Illinois 3(1):19.

Durell, J.S. 1957. A five-year state-wide quail population study in Kentucky. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 11:343-346.

Errington, P.L. 1935. The 1934 drought and southern Iowa bob-white. Iowa Bird Life 5(2):18-21.

Errington, P.L. 1946. Predation and vertebrate populations. Quart. Rev. Biol. 21(2):144-177.

Guthery, F.S. 1987. The question of water. Quail Unlimited Magazine 6(4):18,40.

Guthery, F.S., N.E. Koerth, and D.S. Smith. 1988. Reproduction of northern bobwhites in semiarid environments. J. Wildl. Manage. 52(1):144-149.

Haugen, A.O. 1955. Alabama quail — and quail hunters. Ala. Conserv. 27(2):4-6,25.

Haugen, A.O. 1957. Distinguishing juvenile from adult bobwhite quail. J. Wildl. Manage. 21(1):29-32.

Jackson, A.S. 1962. A pattern to population oscillations of the bobwhite quail in the lower plains grazing ranges of northwest Texas. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 16:120-126.

Kabat, C., and D.R. Thompson. 1963. Wisconsin quail, 1834-1962: population dynamics and habitat management. Wisc. Conserv. Dept. Tech. Bull. 30. 136pp.

Kerr, R.A. 1988. Is the greenhouse here? Science 239(4840): 559-561.

Kerr, R.A. 1989. The global warming is real. Science 243(4891):603.

Kiel, W.H., Jr. 1976. Bobwhite quail population characteristics and management implications in south Texas. Trans. N. Am. Wildl. Conf. 41:407-419.

Klimstra, W.D., and J.L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildl. Monogr. 41. 37pp.

Lehmann, V.W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A & M Univ. Press, College Station TX. 371pp.
Leopold, A., and J.N. Ball. 1931. The quail shortage of 1930. Outdoor America 9(9):14-15,67.
Leopold, A.S. 1939. Age determination in quail. J. Wildl. Manage. 3(3):261-265.
Leopold, A.S., M. Erwin, J. Oh, and B. Browning. 1976. Phytoestrogens: adverse effects on reproduction in California quail. Science 191(4222):98-100.
Murray, R.W. 1958. The effect of food plantings, climate conditions, and land use practices upon the quail population on an experimental area in northwest Florida. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 12:269-274.
Nestler, R.B. 1946. Vitamin A, vital factor in the survival of bobwhites. Trans. N. Am. Wildl. Conf. 11:176-192.
Petrides, G.A., and R.B. Nestler. 1952. Further notes on age determination in juvenile bobwhite quails. J. Wildl. Manage. 16(1):109-110.
Reid, V.H. and P.D. Goodrum. 1960. Bobwhite quail: a product of longleaf pine forests. Trans. N. Am. Wildl. Conf. 25:241-251.
Robinson, T.S. 1957. Climate and bobwhites in Kansas in 1956. Trans. Kansas Acad. Sci. 60(3): 283-287.
Roseberry, J.L. 1974. Relationships between selected population phenomena and annual bobwhite age ratios. J. Wildl. Manage. 38(4):665-673.
Roseberry, J.L., and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Ill. Univ. Press, Carbondale, IL. 259pp.
Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers Univ. Press, New Brunswick, NJ. 418pp.
Speake, D.W. and A.O. Haugen. 1960. Quail reproduction and weather in Alabama. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 14:85-97.
Stanford, J.A. 1953. Poor little Robert — or bobwhite quail and drought in Missouri 1953. Mo. Conserv. 14(11):1-7.
Stanford, J.A. 1972. Bobwhite quail population dynamics: relationships of weather, nesting, production patterns, fall population characteristics, and harvest in Missouri quail. Proc. Bobwhite Quail Symp. 1:115-139.
Stoddard, H.L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, NY. 559pp.
U.S. Dept. Agriculture. 1930. Climatological data. Illinois. Vol 35.
U.S. Dept. Agriculture. 1934. Climatological data. Illinois. Vol 39.
U.S. Dept. Agriculture. 1936. Climatological data. Illinois. Vol 41.
U.S. Dept. Commerce. 1950-1988. Climatological data. Illinois. Vols 55-93.
Wade, D.E. 1938. Drouth intensity measurements and the effects of the 1936 drouth on wildlife. Trans. N. Am. Wildl. Conf. 3:558-569.

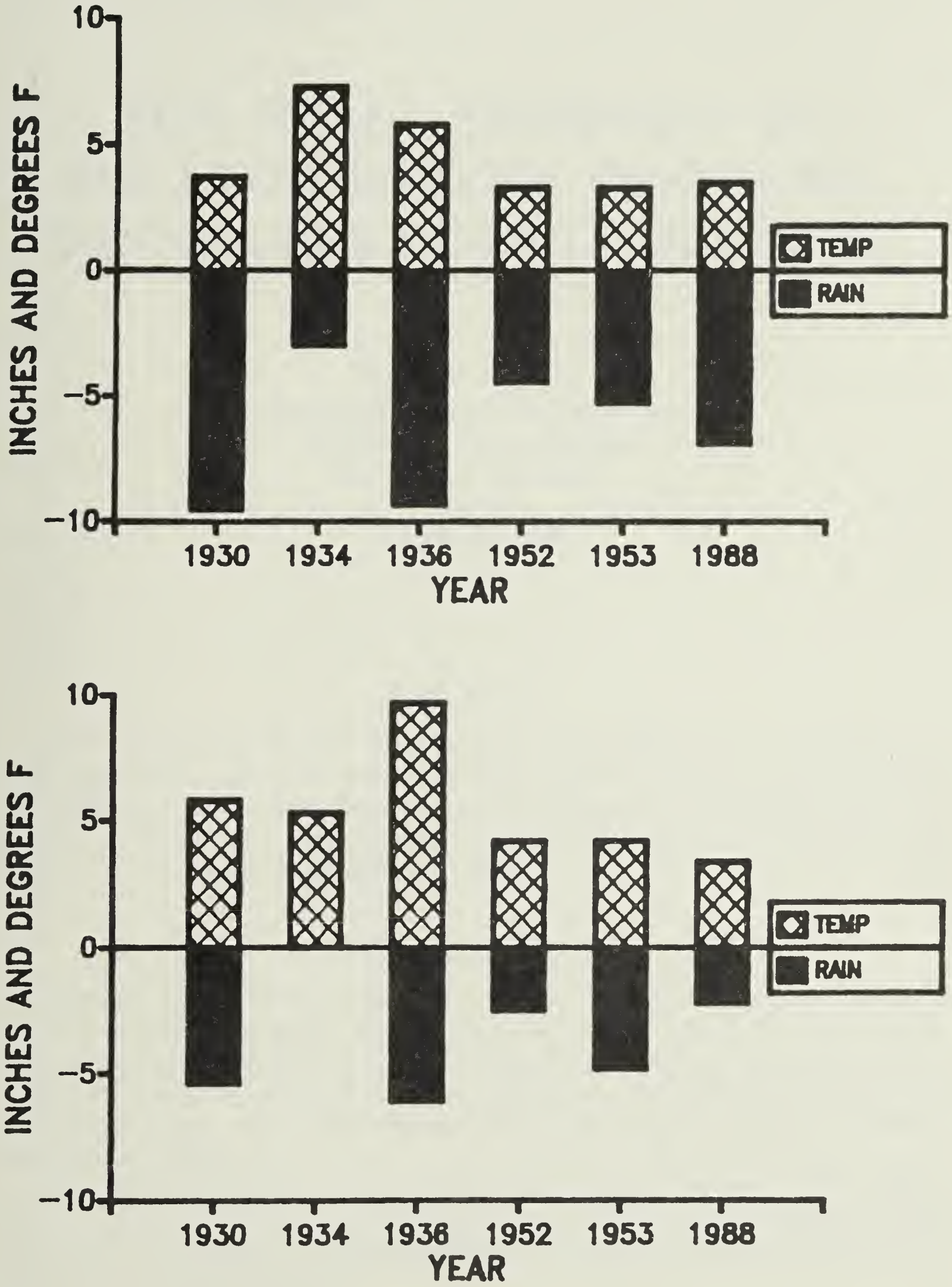

Figure 1. Mean maximum daily temperature and precipitation deviation from normal (1950-1987) for bobwhite egg-laying season, 21 April-18 August (top), and hatching season, 10 June-28 August (bottom).

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THE SMALL MAMMALS OF ROCKTON NATURE PRESERVE, WINNEBAGO COUNTY, ILLINOIS

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ABSTRACT

A survey of the small mammals of Rockton Nature Preserve was conducted on 19-23 September 1988. Five species of mammals were recorded from the site. Sedge meadow and marsh were the most productive communities based on number of species and capture rates. Wetland communities are critical to the conservation of Illinois' small mammal fauna.

INTRODUCTION

Rockton Nature Preserve is a 67 acre tract located 3 miles northwest of Rockton, Winnebago County, Illinois (Section 3, T46N, R1E, 3PM). The nature preserve contains examples of several wetland community types which are restricted in Illinois to the area of Wisconsin glaciation and are representative of the Winnebago Section of the Northeastern Morainal Natural Division of Illinois (Schwegman, 1973).

The flora of Rockton Nature Preserve has been documented (Fell, 1957); however, no studies of the fauna of the preserve are published. The objective of this project was to inventory the small mammals associated with the major community types present on the preserve.

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STUDY AREA AND METHODS

Sedge meadow, marsh, savanna, and successional field were the four major community types selected for sampling. The sedge meadow consists of tall, dense herbaceous vegetation dominated by tussock sedge (*Carex stricta*) and bluejoint grass (*Calamagrostis canadensis*). Other associated plant species include meadow sweet (*Spirea alba*), Canada anemone (*Anemone canadensis*), and Joe-pye-weed (*Eupatorium maculatum*). The marsh community is dominated by cattail (*Typha latifolia*) and is adjacent to the sedge meadow. Tussock sedge, bulrushes (*Scirpus* sp.), and prairie cordgrass (*Spartina pectinata*) also occur here. A disturbed oak savanna persists on sand deposits near the wet areas. Open-grown black oaks (*Quercus velutina*) are the dominant overstory tress. Black cherry (*Prunus serotina*) is also common. The dense understory consists of blackberry (*Rubus* sp.), hazelnut (*Corylus americana*), and the exotic common buckthorn (*Rhamnus cathartica*). A small red pine (*Pinus resinosa*) plantation exists within the savanna. The successional field community is comprised of goldenrods (*Solidago* sp.), ragweed (*Ambrosia artemisiifolia*), and timothy (*Phleum pratense*) and is being invaded by sedges (*Carex* sp.), meadow sweet, and sensitive fern (*Onoclea sensibilis*).

A trapline consisting of 33 trap stations (26 in the marsh) was established in each community. Trapping stations were placed 8 meters apart along the trapline. At each station, 3 Museum Special traps (4 at the last station in each line) were baited with a mixture of rolled oats, peanut butter, and bacon grease. Traps were checked on 4 consecutive nights, 19-23 September 1988. Small mammals captured were placed in plastic bags, labelled, and stored on ice for later identification.

RESULTS AND DISCUSSION

Total trapping effort included 1528 trap-nights; 400 trap-nights each in sedge meadow, savanna, and successional field and 328 in the marsh (Table 1). Trap success (number of animals captured/100 trap-nights) ranged from 3.5 to 16.0 and averaged 9.7 overall. Success was greatest in the wet areas (sedge meadow, marsh) and lowest in the savanna.

Mahan and Heidorn (1984) reported high trap success rates in sedge meadow, wet-mesic prairie and marsh communities and low trap success in savanna communities in Iroquois County, Illinois. However, values reported here for sedge meadow and marsh are 50 and 140 percent higher than those reported by these investigators and are similar to those reported for a Lee County, Illinois sedge meadow by Mahan and Nyboer (1984).

Five species of small mammals, totaling 149 individuals, were captured at Rockton Nature Preserve. The white-footed mouse (*Peromyscus leucopus*) was the most common (N=68), followed by masked shrew (*Sorex cinereus*) (33), meadow vole (*Microtus pennsylvanicus*) (23), short-tailed shrew (*Blarina brevicauda*) (13), and meadow jumping mouse (*Zapus hudsonicus*) (12) (Table 1).

The white-footed mouse and short-tailed shrew were the only species encountered in all 4 communities. White-footed mice were the most common species in sedge meadow, savanna, and successional field communities, while short-tailed shrews were common only in the sedge meadow. The white-footed mouse is commonly found in woods, forest edges, and other brushy or woody habitats (Hoffmeister and Mohr, 1957). Therefore, its abundance in the sedge meadow and

successional field and its occurrence in the marsh is notable. Mahan and Heidorn (1984) did not record this species from prairie, sedge meadow, or marsh communities in Iroquois County. However, it has been recorded from Lee County sedge meadows and prairies (Mahan and Nyboer, 1984). In both these previous surveys, white-footed mice were most common in pine plantations, a trend not evident in this survey (no captures occurred where the savanna trapline crossed through the pine plantation — 4 stations, 12 traps).

Short-tailed shrews are often associated with moist litter on forest floors and moist, thick duff in meadows (Getz, 1961). While common in the sedge meadow in this survey, this species has been found to be very common in sedge meadow, wet prairie, and successional fields (Mahan and Heidorn, 1984), as well as mesic sand prairies, sedge meadow, and bottomland forest (Mahan and Nyboer, 1984). The short-tailed shrew can be one of the most abundant small mammals in woodland areas (Hoffmeister and Mohr, 1957, Mumford and Whitaker, 1982) and yet was rare in these habitats at Rockton Nature Preserve.

The masked shrew was limited to moist or wet areas and was particularly abundant in sedge meadow. As with most shrews in the genus *Sorex*, the masked shrew seems to prefer moist or wet habitats with dense ground cover (Hamilton and Whitaker, 1979). It has been recorded as being less tolerant of low humidity than the short-tailed shrew (Getz, 1961). In Lee County, 18 of 20 individuals captured were taken in sedge meadow (Mahan and Nyboer, 1984), while sedge meadow, shrub prairie, and flatwoods (a seasonally wet community) accounted for 10 of 11 masked shrews captured in Iroquois County (Mahan and Heidorn, 1984).

Meadow voles were captured only in the tall, dense herbaceous vegetation of the sedge meadow and marsh and were the dominant species in the latter. No meadow voles were captured in the successional field where vegetation was less dense but much shorter than in the sedge meadow or marsh. The meadow vole is a species of damp, grassy areas and is fairly abundant in northern Illinois (Hoffmeister and Mohr, 1957). Similar habitat affinities were recorded in Lee and Iroquois Counties where wet habitats accounted for 13 of 15 and 21 of 25 captures, respectively (Mahan and Nyboer, 1984; Mahan and Heidorn, 1984).

Meadow jumping mice were captured in all open habitats but were notably more common in marsh and sedge meadow. This species is frequently encountered in grassy areas near streams or ponds (Hamilton and Whitaker, 1979), but is generally considered to be uncommon throughout Illinois (Hoffmeister and Mohr, 1957). In Indiana, Mumford and Whitaker (1982) note that the meadow jumping mouse is often found in moist situations but felt this was more related to lack of disturbance and presence of dense ground cover than directly to moisture. Its primary habitats in Lee County were mesic sand prairie and sedge meadow (Mahan and Nyboer, 1984). Only 2 individuals were caught in 990 trap-nights in Iroquois County, however, both were taken in wet habitats (Mahan and Heidorn, 1984).

The current study, in conjunction with the investigations in Lee and Iroquois Counties, clearly indicate the importance and productivity of sedge meadow, wet prairie, and marsh communities to small mammal populations. These habitats consistently harbor the highest population levels and greatest number of species of all communities investigated as determined by early autumn traplines. These areas may be particularly important for maintaining shrew populations as moisture is a

limiting factor for many of these species (Getz, 1961). The preservation and maintenance of these communities is critical to the conservation of the native small mammal fauna.

Further, wetlands significantly disturbed by human activities (e.g. grazing), though recovering botanically, do not support small mammal communities comparable to less disturbed areas (successional field vs. sedge meadow). Nearby undisturbed sites must also be maintained as a source of plant and animal colonists for recovery of disturbed sites.

SUMMARY

The four major community types at Rockton Nature Preserve were sampled for small mammals. Wet communities were the most biologically rich areas sampled and harbored species not found or uncommon in other community types. No threatened or endangered species were encountered. While the preservation of wetlands has been discussed in terms of its impact on waterfowl, songbirds, reptiles, and amphibians, these habitats are also of great importance in the conservation of Illinois' small mammals.

ACKNOWLEDGMENTS

Carl Becker provided the impetus for this project and the Illinois Nature Preserves Commission granted permission for trapping on the nature preserve. Jeff Pontnack provided invaluable assistance with field work and data collection. Fran Harty critically reviewed the manuscript.

LITERATURE CITED

Fell, E.W. 1957. Plants of a northern Illinois sand deposit. Am. Midl. Nat. 57:441-451.

Getz, L.L. 1961. Factors influencing the local distribution of shrews. Am. Midl. Nat. 65:67-88.

Hamilton, W.J., Jr. and J.O. Whitaker, Jr. 1979. Mammals of the Eastern United States. Cornell University Press, Ithaca, NY. 346 pp.

Hoffmeister, D.F. and C.O. Mohr. 1957. Fieldbook of Illinois Mammals. Dover Publ., NY. 233 pp.

Mahan, C.J. and R.R. Heidorn. 1984. The mammals of Iroquois County Conservation Area. Trans. Ill. St. Acad. Sci. 77:23-28.

Mahan, C.J. and R.W. Nyboer. 1984. Small mammal survey at Green River Conservation Area. Unpubl. Report. Ill. Dept. Conservation, Springfield, IL. 7 pp.

Mumford, R.E. and J.O. Whitaker. 1982. Mammals of Indiana. Indiana Univ. Press, Bloomington. 537pp.

Schwegman, J.E. 1973. The Natural Divisions of Illinois. Ill. Nature Preserves Commission. Springfield, IL. 32 pp.

Table 1. Number of individuals and species of small mammals captured within each natural community at Rockton Nature Preserve, Winnebago County, Illinois, 19-23 September 1988.

	NATURAL COMMUNITY					
SPECIES	Sedge Meadow	Marsh	Oak Savanna	Successional Field	TOTAL	PERCENT
Masked shrew	19	8	0	6	33	22.1
Short-tailed shrew	9	2	1	1	13	8.7
White-footed mouse	24	7	13	24	68	45.6
Meadow vole	8	15	0	0	23	15.4
Meadow jumping mouse	4	7	0	1	12	8.0
TOTAL INDIVIDUALS	64	39	14	32	149	
TOTAL SPECIES	5	5	2	4	5	
NO. TRAP-NIGHTS	400	328	400	400	1528	
TRAP SUCCESS (%)	16.0	11.9	3.5	8.0	9.7	

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SUBSPECIFIC COMPOSITION OF THE ILLINOIS CANADA GOOSE HARVEST

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ABSTRACT

Carcass parts and measurements were collected from adult Canada geese (*Branta canadensis*) in southern Illinois during the November-December hunting seasons in 1982 and 1983 (N=256), and in central and northern Illinois in 1986 and 1987 (N=565). Subspecific composition varied little between years, but significantly ($P<0.01$) between regions of the state. Statewide composition (±1%) was 2% *B. c. hutchinsii*, 82% *B. c. interior*, and 16% *B. c. maxima* in 1986 and 1987.

INTRODUCTION

Current harvest management strategies for Canada geese (*Branta canadensis*) in the Mississippi Flyway involve setting statewide quotas primarily meant to control harvest of *B. c. interior* from the Eastern Prairie (EPP), Mississippi Valley (MVP) and Tennessee Valley (TVP) populations (Unpubl. Reps., Mississippi Flyway Council). For example, annual statewide quotas for Illinois are designed primarily to control harvest of interior Canada geese of the MVP. However,

Canada goose harvest in the Mississippi Flyway also includes *B. c. hutchinsii* and *B. c. maxima* (Bellrose 1980, Spitzkeit and Tacha 1986, Tacha et al. 1987). Appropriate statewide quotas therefore require knowing proportions of the 3 subspecies in the harvest of each state. This need is underscored by recent rapid increases in *B. c. maxima* populations (Unpubl. Reps. Mississippi Flyway Council and Illinois Department of Conservation; Lawrence 1987). Our objectives are to provide reliable estimates of the subspecific composition of the Illinois Canada goose harvest; compare these estimates to those currently employed in setting harvest quotas, and evaluate the results in terms of improving Canada goose harvest management in the Mississippi Flyway.

METHODS

Carcass parts including the head, one leg, and the fleshy parts of the tail (including the cloaca) were collected from 565 adult Canada geese (Table 1) in central and northern Illinois (Regions I-IV, Fig. 1) during November-December hunting seasons in 1986 and 1987. Carcass samples were generally representative of the county by county distribution of harvest within regions, and harvest chronology throughout the hunting season. Age and sex were determined from cloacal examinations (Hanson 1967). Culmen and tarsus measurements (nearest mm) were obtained from heads and legs and used in discriminate function analyses that were >95% accurate in identifying subspecies (Spitzkeit and Tacha 1986).

Subspecific composition was calculated for the 6 regions and subregions of the state to insure sampling was geographically representative of the statewide harvest distribution. By calculating subspecies composition for each region, and weighting regional composition by proportion of statewide harvest, we were able to avoid effects of oversampling in Regions IB and II where resident flocks of *B. c. maxima* occur. Data for Region V were obtained from Spitzkeit and Tacha (1986) and assumed reflective of 1986-87 Region V harvests because a) their data from 1983-84 showed no change among years in subspecific composition and b) over 97% of harvest was 1 subspecies (*B. c. interior*). Harvest estimates by region for 1986 and 1987 were obtained from hunter surveys conducted by the Illinois Department of Conservation (see Anderson 1987 for methods).

Discriminate function analyses, data summaries, and chi-square tests for variation in subspecific composition were conducted using the Statistical Analysis System (SAS Institute Inc. 1982). Statistical tests were considered significant with $P < 0.05$.

RESULTS AND DISCUSSION

Subspecific composition varied little between years, but significantly ($P < 0.01$) between regions (Table 1). Most regional variation was due to higher percentages of *B. c. maxima* in Regions I-IV than in Region V, and the higher percentage of *B. c. hutchinsii* in Regions III and IV (see Table 1 and Fig. 1). Statewide composition (±1%) was 2% *B. c. hutchinsii*, 82% *B. c. interior*, and 16% *B. c. maxima*.

The U.S. Fish and Wildlife Service (USFWS) and Mississippi Flyway Council (MFC) currently assume that 8% of the Illinois statewide Canada goose harvest is *B. c. maxima* based on analysis of leg band recoveries (Unpubl. Reps., MFC). Our

data indicating a consistent 16% *B. c. maxima* in the statewide harvest suggest that results of these leg-band analyses are seriously underestimating the harvest of giant Canada geese (*B. c. maxima*) and overestimating the harvest of *B. c. interior* in Illinois. Leg-band analyses may (or may not) yield reliable estimates of proportions of the *B. c. interior* harvest that are EPP, MVP, and TVP within Illinois and other Mississippi Flyway states. However, leg-band analyses have not yielded reliable estimates of subspecific composition in Illinois, and may yield biased estimates in other states.

We believe the statewide harvest quotas meant primarily to protect EPP, MVP and TVP Canada geese should be based on reliable estimates of subspecific and population composition. States of the MFC should undertake research to estimate subspecific composition using techniques similar to ours. However, discriminate functions of Spitzkeit and Tacha (1986) are designed only for use in the major MVP harvest states; different discriminate analyses will be needed elsewhere.

Increased precision is needed in management of the Canada goose harvest in the Mississippi Flyway. The abilities to monitor annual recruitment, and adjust harvest accordingly, need to be developed for each population (giant Canada geese should be considered separately). This will require improved midwinter inventory and production survey techniques, as well as coordinated efforts among MFC states to delineate the collective harvest of each population (see also Tacha et al. 1988). Numbers of geese in the EPP, MVP, TVP, and *B. c. maxima* populations often change rapidly, suggesting that harvest composition surveys should be perceived as ongoing management activities conducted at periodic intervals (e.g., every 5 years).

ACKNOWLEDGMENTS

This study was funded by the Illinois Department of Conservation (IDOC). We thank A. Woolf for manuscript review, the many hunters who donated goose parts, and IDOC personnel that assisted in collecting goose parts.

LITERATURE CITED

Anderson, W.L. 1987. Illinois waterfowl harvest, hunter activity and attitudes toward restrictive duck hunting regulations and steel shot in 1985. Ill. Dep. Conserv., Div. Wildl. Resourc., Periodic Rep. No. 59. 12pp.

Bellrose, F.C. 1980. Ducks, geese and swans of North America. Third ed. Stackpole Books, Harrisburg, PA. 540pp.

Hanson, H.C. 1967. Characters of age, sex, and sexual maturity in Canada geese. Ill. Nat. Hist. Surv. Biol. Notes 49. 15pp.

Lawrence, J.S. 1987. Population ecology of giant Canada geese in west-central Illinois. Ph.D. Thesis, So. Ill. Univ., Carbondale 190pp.

Spitzkeit, J.W., and T.C. Tacha. 1986. Subspecific composition of Canada geese wintering in southern Illinois. Trans. Ill. State Acad. Sci. 19:171-173.

Tacha, T.C., D.D. Thornburg, and R.A. Williamson. 1987. Bias of tail fan surveys for estimating Canada goose age ratios. Wildl. Soc. Bull. 15:533-534.

Tacha, T.C., A. Woolf, and W.D. Klimstra. 1988. Breeding distribution and subpopulations of Mississippi Valley Population Canada geese. J. Wildl. Manage. 52:689-693.

Table 1. Estimated subspecific composition of the 1986 and 1987 Illinois Canada goose harvests.

Region[a]	Year	Harvest[b]	Sample[c]	% composition		
				hutchinsii	*interior*	*maxima*
IA	1986	916	18	0	67	33
	1987	1,050	5	0	80	20
	Total	1,966	23	0	70	30
IB[d]	1986	6,774	119	6	38	56
	1987	3,994	302	3	37	60
	Total	10,768	421	4	37	59
II[e]	1986	2,157	39	0	44	56
	1987	2,719	20	0	50	50
	Total	4,876	59	0	46	54
III & IV	1986	2,644	20	10	50	40
	1987	2,813	42	21	64	15
	Total	5,457	62	17	60	23
V[f]	1986	32,366	—	—	—	—
	1987	23,386	—	—	—	—
	Total	55,752	256	1	97	2
Statewide[g]	1986	44,757	196	2	82	16
	1987	33,962	369	2	83	15
	Total	78,719	821	2	82	16

[a]See Fig. 1 for definitions of regions.

[b]Numbers of Canada geese harvested by region are from preliminary estimates from mail surveys of hunters purchasing Illinois duck stamps in 1986 and 1987 (Unpubl. data, IDOC).

[c]Numbers of harvested geese from which parts and measurements were obtained.

[d]Region IB includes the Tri-County Zone and associated breeding population of *B. c. maxima.*

[e]Region II includes the breeding range of a resident flock of *B. c. maxima.*

[f]Region V includes Rend Lake and Southern Illinois Quota Zones. Subspecific composition is from Spitzkeit and Tacha (1986).

[g]Statewide composition estimates are based on regional compositions weighted by the respective proportion of statewide harvest.

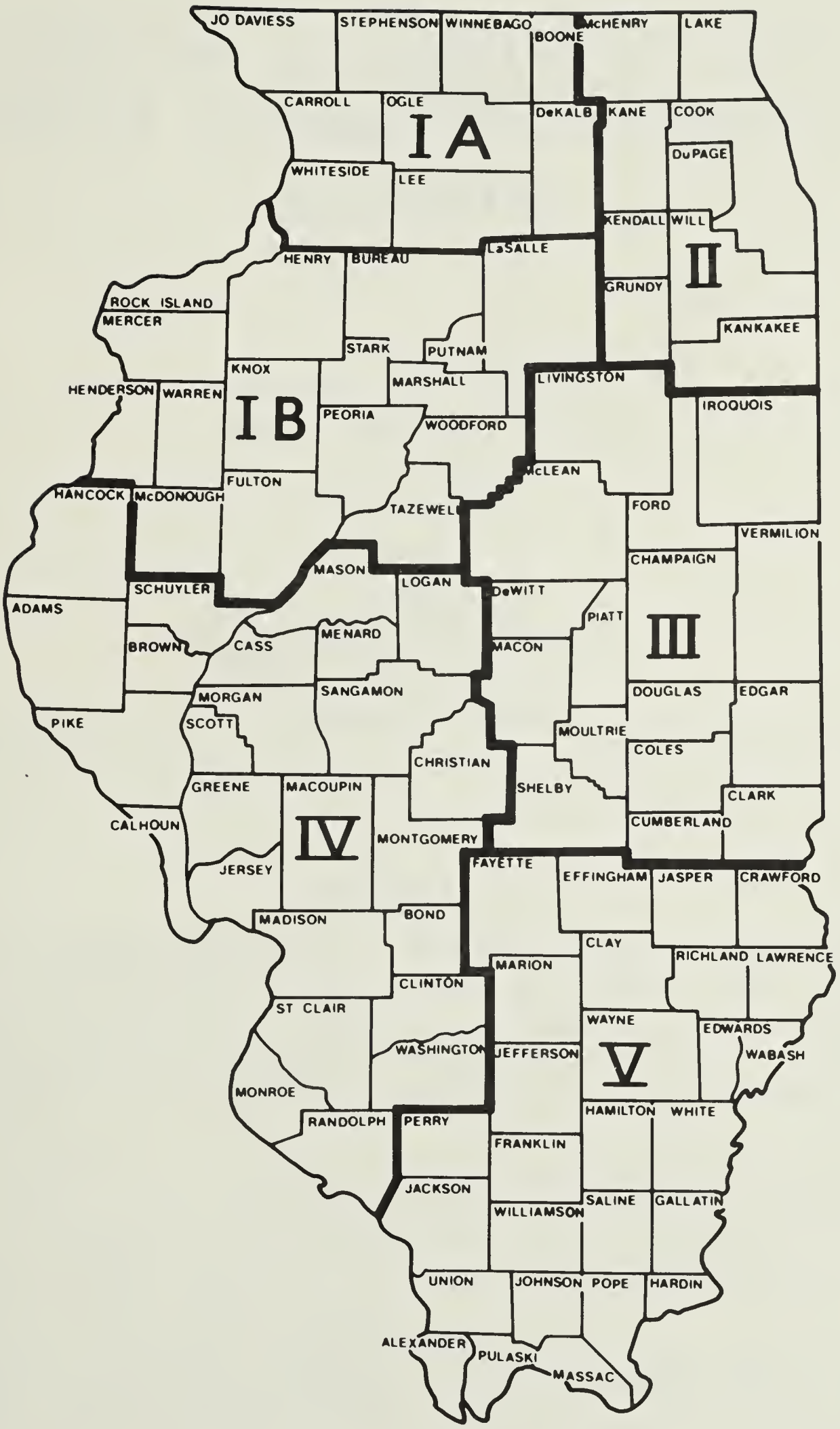

Figure 1. Administrative regions of the Illinois Department of Conservation used in sampling to estimate subspecific composition of the Illinois Canada goose harvest.

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RECORD OF A CERVUS SP. ANTLER FROM LIVINGSTON COUNTY, ILLINOIS

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ABSTRACT

In June of 1985, the basal portion of a Cervid antler was discovered partially buried in a sand/gravel bar of Rook's Creek, approximately 5 km northeast of Graymont in Livingston County, Illinois (Rook's Creek Township, Section 15, R4E, T28N). Size and shape of the fragment indicated it to be part of a *Cervus* sp. antler, rather than that of the presently-ubiquitous Illinois Cervid, *Odocoileus virginianus* (Figure 1).

The fragment is part of a shed right antler. Overall length is 256 mm with a burr diameter of 76 mm and a single bifurcation 125 mm above the base. The main beam is hollow and a large portion of the burr is absent; the overall degenerative state of the fragment suggests a subfossilized condition. There is no evidence of tooling to indicate its use as an aboriginal artifact.

Although a state-wide, prehistoric distribution of *Cervus* sp. has been suggested (Hoffmeister and Mohr, 1972), bona fide documentation in Illinois is limited and patchy. Purdue and Styles (1987) reported occurrences of *Cervus elaphus* during the Holocene from archaeological sites in Madison, Randolph, and St. Clair Counties. Sightings and/or tracks of *Cervus canadensis* were reported in the late 1700's through the early 1800's in Cook, Randolph, Peoria, and Wabash Counties

(Murie, 1951), and a set of *C. canadensis* antlers was reportedly discovered in Lake County (Cory, 1912), *C. canadensis* is generally thought to have been extirpated statewide by the mid-1800's (Hoffmeister and Mohr, 1972). The discovery of this antler fragment represents the first documented historical occurrence of *Cervus* sp. in Livingston County.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Lawrence A. Conrad of the Sociology and Anthropology Department, Western Illinois University for examining the specimen for evidence of tool use.

LITERATURE CITED

Cory, C.B. 1912. The mammals of Illinois and Wisconsin. Publication 153, Zoological Series Vol. 11. Field Museum of Natural History, Chicago, IL. 502 p.

Hoffmeister, D.F. and C.O. Mohr. 1972. Fieldbook of Illinois mammals. Dover Publications, New York, NY. 233 p.

Murie, O.J. 1951. The elk of North America. The Stackpole Company, Harrisburg, PA. 376 p.

Purdue, J.R. and B.W. Styles. 1987. Changes in the mammalian fauna of Illinois and Missouri during the late Pleistocene and Holocene. p.144-174 *In* R.W. Graham, H.A. Semken, Jr., and M.A. Graham (eds.), Late Quaternary mammalian biogeography and environments of the Great Plains and prairies. Scientific Papers, Vol. 22. Illinois State Museum, Springfield, IL. 491 p.

Figure 1. The antler fragment presently is in the possession of the author, J.D. Hildenbrand.

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THE FIRST RECORD OF THE QUILLBACK CARPSUCKER (CARPIODES CYPRINUS) IN ILLINOIS WATERS OF LAKE MICHIGAN

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ABSTRACT

This is the first record of a quillback carpsucker in Illinois waters of Lake Michigan. The fish was captured by electro-shocking in Jackson Park Harbor in Chicago, Illinois on June 21, 1989. The total length of the fish was 31.7 cm and it weighed 448.5 g. The quillback carpsucker is found primarily in streams and rivers in central and northern portion of Illinois but has not been reported in Illinois waters of Lake Michigan (Smith, 1979). There is only one documented report of the quillback carpsucker in Lake Michigan and that fish was captured at the extreme southwestern portion of Green Bay in Wisconsin (Becker, 1976).

ACKNOWLEDGMENTS

We thank Dr. Lawrence Page for confirming the identification of the specimen. It now resides in the fish collection at the Illinois Natural History Survey (catalogued as INHS 64805) in Champaign, Illinois. The collection of this specimen was part of a project funded by the Illinois Department of Conservation, F-93-R.

LITERATURE CITED

Becker, G.C. 1976. Environmental status of the Lake Michigan region. Volume 17. Inland fishes of the Lake Michigan drainage basin. Argonne National Laboratory ANL/ES Vol. 17.
Smith, P.W. 1979. The Fishes of Illinois. University of Illinois Press. Champaign, Illinois.

ACADEMY NOTE:

The next Annual Meeting of the Illinois State Academy of Science will be held on October 26-27, 1990. This 83rd Annual Meeting will be held on the University of Illinois, Urbana campus. The meetings will be co-sponsored by the Natural History Survey and the University of Illinois, Urbana.

This is the last volume of the Transactions for which I will serve as editor. I have sincerely enjoyed this opportunity and have found it to be a fulfilling and enriching experience. Dr. Teresa North will succeed me as editor of the Transactions. Therefore, please address all future communications regarding the Transactions to:

Dr. Teresa North
Western Illinois University
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Respectfully,

Paul Walker, Professor
Animal Science

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